Edward Pinkowski
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EXPOSITORY WRITING

Interpretation

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The Woman's Suffrage Question

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EXPOSITORY WRITING

Materials for a College Course in Exposition by Analysis and Imitation

COMPILED AND EDITED, WITH QUESTIONS AND EXERCISES, BY

MAURICE GARLAND FULTON

PROFESSOR OF ENGLISH IN DAVIDSON COLLEGE

Periodic sentence – In a period sense
suspended until end; sentence where thought
[illegible] turned loose.

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PREFACE

In preparing this book of selections illustrative of some of the various phases of expository writing, for use either in the general Freshman course in English composition or in a special course in exposition to be taken in the Sophomore or Junior year, I have had in mind certain definite aims, the principal of which are the following: First, to make definite and systematic application of the method of learning to write through the examination and imitation of good models. Second, to centre attention upon exposition since it is the kind of writing that is most directly serviceable in practical life and that most readily exemplifies the essential qualities of effective composition—accuracy, logicalness, and economy of presentation. Third, to draw the selections chiefly from the field of scientific writing because of the intrinsic interest of such subject-matter to young persons. Fourth to have the selections of such length that the analysis of them will afford a "severe logical setting-up exercise." As some of the aims I have briefly named above may be new—though they are not untested—I may be pardoned for setting them forth somewhat more fully and pointing out the ways in which this book embodies them.

The study of composition by the method of analysis and imitation is both psychologically and pedagogically sound. To obtain principles of effective writing, not by conning from the pages of a text-book ready-made rules and philosophizings upon principles of structure and style, but through one's own self-effort in the examination and study of the actual expression of ideas in the writing of those who have written successfully, is to add interest and effectiveness to the study of composition. To the careful analysis of models of good writing must be added the imitation of their principles of structure and style in the

student's own practice upon subjects similar in method and type. The quantity of writing may with advantage be decreased in the interest of the careful study of models, for it is questionable whether our present methods of teaching composition in the colleges do not tend to set a quantitative rather than a qualitative standard for the work in composition.

This book aims to give material for conducting a course in composition by this method of analysis and imitation. No attempt has been made to teach systematic rhetoric. The purpose has been the simple one of opening in a practical way the student's eyes to some of the major problems of writing. In order to make the analysis of the selections adequate and definite, study questions have been included. These questions attempt to challenge the student's curiosity, to set a problem before him for solution, to rouse thought and set it going, rather than to give information. The sets of questions are of differing degrees of fullness, but are never designedly exhaustive or restrictive. They should be increased or decreased, or otherwise modified as the instructor sees fit. Nor is the order of the selections to be rigidly observed. To give system to the book as a whole and to avoid repetitions, each set of questions has been confined to a single principle or set of principles, and while this fact gives to the book a sequence and progression corresponding somewhat to the growth in comprehension and facility to be expected of the average student, such arrangement is not intended as a fetter upon the teacher. The exercises following the questions are intended to afford material for practice in composition. The subjects chosen for these exercises are intended to be merely suggestive, and should be freely changed or adapted to meet the interests and proficiency of a particular class.

The selections in this volume are broadly illustrative of expository types and methods. In Part I exposition is taken as the norm for the general principles of composition relating to the whole composition, the paragraph, the sentence, and the word. Students who are well grounded in these matters may be allowed to omit this part of the book, or to pass over it

rapidly as a review. With Part II begins the study of expository methods. Examples of definition have been placed first; these are followed by selections showing the complementary process of classification and division. The remaining selections illustrate such matters as the statement of the problem involved in a piece of investigation, the straightforward and complete exposition of a single definite topic, the skilful treatment of material demanding special adaptation to audience or reader, methods of handling large and complex masses of details, the treatment of subject-matter involving unusual difficulties and requiring special devices of illustration, and finally the use of descriptive and narrative methods for purposes of exposition.

The selection of material from the field of science rather than from that of literature in the narrower sense, perhaps requires a few words of explanation. Undeniably writing of fact makes more of an appeal to the average young person than writing of literature. It is interesting in itself to the student, because he is essentially in the popular science age. Moreover, it emphasizes more strongly than other kinds of writing accuracy, directness, conciseness, power of system and organization, sense of logical relationships, and the student more easily perceives these qualities in the direct expression that characterizes scientific writing than in the suggestiveness and indirectness of artistic expression. In still another way the study of scientific literature may be made of most helpful service to the student. It may be made a means of introducing him to certain procedures of scientific method as well as to the adequate and convincing presentation of scientific results.

The selections presented are complete articles, chapters, or other large component parts of books, rather than excerpts of a few paragraphs, in order that the study of them may afford training in the power to think straight, which is so little a part of the rising generation. It is the duty of the modern college not to truckle to this weakness, but to cure it. In few ways can the strengthening and developing of the thinking power be more readily secured than by the careful analysis of expository

selections. Hence the selections in this book are of greater length than is usual in similar volumes.

I cannot send this book forth without some expression of my obligations to those who have helped in its equipment. It owes much to the copyrighted material it contains, and although due acknowledgments for permission to reprint are scattered through its pages, it is a pleasure here to record in a general way my grateful appreciation of these generous permissions. It would be impossible and unprofitable to name all the works on composition and rhetoric I have consulted. Through class-room use I am especially familiar with Scott and Denney's *Paragraph-Writing* and *Composition-Rhetoric*, Baldwin's *A College Manual of Rhetoric* and *Composition, Oral and Written*, Canby's *English Composition in Theory and Practice*, Genung's *Practical Elements of Rhetoric* and *Working Principles of Rhetoric*, and I have no doubt that I have borrowed more of their ideas than is anywhere formally acknowledged. Earle's *The Theory and Practice of Technical Writing*—a book that parallels in a theoretical way the studies in this book—came to hand while I was reading this book in proof, and I have been able to avail myself to some extent of suggestions from it.

I would also express my indebtedness to Mr. Royal A. Abbott of the Commercial High School, Brooklyn, for valuable assistance. Several years ago, when I began the preparation of a book similar in some respects to this one, I invited Mr. Abbott, then a colleague in the department of rhetoric at the University of Michigan, to collaborate with me. Our paths soon after diverged, and I have finished the book, so modifying and enlarging the original plan, however, that it is practically an independent book. Mr. Abbott suggested several of the selections and prepared the questions accompanying Stevenson's *Apology for Idlers*, Morgan's *Definition of Instinctive Behavior*, Ely's *Types of Monopolies*, George's *Progress and Poverty*, and Tyndall's *Scope and Limits of Scientific Materialism*.

M. G. F.

DAVIDSON, N. C., *November*, 1911.

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INTRODUCTION

I

THE NATURE OF EXPOSITION

THE search for a satisfying definition of exposition soon reveals that books on composition and rhetoric give definitions of varying degrees of comprehensiveness. One writer will designate it broadly as "the explanation of ideas";[1] another, as "the art of stating facts clearly, so that the reader will understand them";[2] a third, as "the succinct and orderly setting forth of some piece of knowledge."[3] Other writers will define it more specifically as "the fixing of meaning by generalization, that is, the exhibiting of objects, material or spiritual, as conceived and organized in thought,"[4] or as "the kind of discourse in which the writer's aim is to make others see the meaning of some idea as clearly as he himself sees it; its subject matter is general ideas, laws, or principles, not (as in description and narration) particular things."[5] Although any one of these definitions is more or less adequate, we may attempt to come to a clearer understanding of the nature of exposition by ascertaining the characteristics that distinguish it as a form of composition from the other kinds of writing—description, narrative, and argument. The particular characteristics of exposition will be discussed under the three heads of subject-matter, purpose, and mood.

[1] Mitchill and Carpenter's *Exposition in Class-room Practice*, p. 1.
[2] Canby's *English Composition in Theory and Practice*, p. 1.
[3] Baldwin's *A College Manual of Rhetoric*, p. 40.
[4] Genung's *Working Principles of Rhetoric*, p. 554.
[5] Scott and Denney's *Composition-Rhetoric*, p. 302.

THE SUBJECT-MATTER OF EXPOSITION

Broadly speaking, the material of all writing is experience. In experience two aspects or elements may be osberved, corresponding to whether our knowledge is confined to bare acquaintance with externals, or whether it embraces an understanding of the meaning of a given experience. The first of these elements may be called the element of *fact*. This is the concrete element, knowledge of which is derived through the sense-organs. The second element may be called the element of *meaning*. This is the abstract element, to knowledge of which we ascend by rallying our wits, and beginning to notice, to analyze, to think, until finally the mind shapes for itself an interpretation of the meaning or significance of the experience.

In reality, given experiences do not belong rigidly under either of these aspects. They have been spoken of as distinct and distinguishable elements mainly for convenience, and in order to accentuate their presence. As a matter of fact, they are constantly merged and are not separable. If, for instance, we look at a building, we not only receive impressions of external appearance, such as size, shape, color, and the like, but simultaneously we begin an interpretation of these experiences. We begin to think of the nature, or the significance, or the function of the building—more or less vaguely at first, it may be, but with gradually increasing definiteness. In short, by mental processes we come to some generalization about it.

The writer, however, is able more or less completely to separate these two elements in his writing. He may simply show the appearance of some object or the details of an event with little or no regard to their significance, or he may merely explain an operation or process or idea, disregarding the concrete element in it. This being the case, we are able to divide writing into two large classes. There is first that which concerns itself with the outer world of scenes and happenings. There is secondly that which deals with the inner world of thoughts and the relations of thoughts. To the first of these classes evidently belong description with its endeavor to show

the appearance of the individual object, and narrative with its aim of recounting the details and particulars of some transaction or event. To the second class belong exposition and argument. It is not needful in this connection to dwell upon the differences between exposition and argument; more to the point for the present purpose is their likeness in having for their subject-matter, not, as in the case of description and narrative, particular things, but general ideas or abstract qualities. In the words of Professor Genung, "We are to remember that in exposition we are dealing not with an object whose parts and peculiarities are displayed in space before us, as in description; nor with an event, whose incidents succeed each other in time, as narration; but with a man-made concept, whose aspects and divisions are discerned by the laws of thought and association that exist in human minds."[1]

There are, however, some cases where exposition deals with the concrete and the individual. If one should carefully examine a typewriter, and then write out a full description of its parts—keyboard, type-bars, carriage, platen, ribbon, index, etc.—giving the form and position of each and even the material of which it is made, or if one should visit a great newspaper building, and afterwards write an account of the printing of the paper from the writing of the news to the delivery of the printed sheet to the delivery wagons, would he, in the one case, be writing a description, in the other, a narrative? In both of these two examples, we have the concrete and individual subject-matter characteristic of description and narrative, but evidently, in neither case is the writer dealing merely with the element of fact in his subject-matter. While he may not seem to get very far away from the element of fact in either instance, nevertheless, in the case of a typewriter, his endeavor is not so much to induce in the mind of the reader a picture of the typewriter and its parts as to explain its mechanism and its use; and in the case of the visit to the newspaper building, the writer's purpose is not to relate interestingly the happening of his visit, but to explain the process of making a newspaper.

[1] *Practical Elements of Rhetoric*, p. 386.

Such portrayal of the concrete, although loosely called description or narrative, is more exactly designated as exposition. Nor are such portrayals simply narrative or description converted into exposition by single occurrences or objects of a similar kind becoming blended into a composite—what is commonly called generalized narrative or description. They are rather instances in which the general class, the type, is presented as an individual, and the individual is made to serve as a type.

Instances such as have just been described of exposition presenting the type through the individual are, however, exceptions rather than the rule. It still remains true that the most commonly found subject-matter of exposition is the abstract and the general. These abstractions and generalizations are divisible into two classes—terms and propositions. "An object to be expounded expresses either an idea or the relation between ideas. Hence its form is either a term or a proposition. Though exposition may be applied to any object—an object described, or an event narrated, as well as an object of thought—yet in its state as a concept or generalization, the object must be reduced to one of these forms; it must either name an idea, or make an assertion in regard to it."[1] That is, exposition may take a term like *psychology*, *nature*, *erosion*, *art*, or *culture*, and seek to set forth clearly what it is, what are its essential qualities, how much it includes, what it excludes, how it differs from other similar ideas, into what kinds it is divided. Or, exposition may take a general proposition, such as "Natural phenomena are uniform," or "Education is beneficial in all the pursuits of life," or "Honesty is the best policy," or "The area of a triangle is equal to half the product of the base and the perpendicular," and, without assuming the truth or falsity of the proposition, endeavor to give an explication of it—elucidating the words of the original statement, suggesting what is implied in the idea expressed, hinting at its relationship to other ideas, and possibly indicating its application.

[1] Genung's *Practical Elements of Rhetoric*, p. 386.

THE PURPOSE OF EXPOSITION

Exposition is further distinguished from other kinds of composition by its purpose. Another broad twofold grouping of writing according to the writer's purpose is given in De Quincey's well-known division of literature. "In the great social organ," says he in his *Essay on Pope*, "which we may collectively call literature, there may be distinguished two separate offices that may blend and often do so. . . . There is, first, the literature of knowledge, and, secondly, the literature of power. The function of the first is to teach, the function of the second to move." De Quincey further points out that the first kind of writing appeals to the intellect, the second to the emotions and the imagination. Writing that appeals to the intellect may be said to have as its general purpose *instruction;* while writing that stirs the emotions and the imagination has as its general purpose *entertainment.* Entertainment is primarily the aim of narration and description; instruction is the main purpose of argument and exposition.

It frequently happens that we must determine whether or not a given piece of writing is exposition from a careful consideration of the purpose of the writer. As we have seen, exposition sometimes deals with the particular and the concrete, and the classification of such expositions is oftentimes a matter of doubt. Among the selections in the latter part of this book is one describing the surface of the moon. This clearly deals with a particular object. Another of these selections tells the life history of a salmon. It also appears to deal with an individual member of the species. Although we might be inclined to classify the one selection as description and the other as narrative, we should find upon more careful consideration of the purpose of the writers that indubitably they were using the specific and concrete in order to show its significance or to set forth some generalization in regard to it. In the selection, *The Surface of the Moon*, the purpose of the writer is not to stimulate our imagination to form mental pictures of the surface of the moon, but to explain clearly to the understanding certain

facts in regard to this satellite. In the case of the selection entitled *The Story of a Salmon*, the purpose of the writer is not simply to tell a story about a salmon, but rather to elucidate the development and the habits of this species of fish, the story form being chosen because of the greater interest. Despite such seeming exceptions, it still remains true that the purpose of exposition is to show the essence, the underlying principle, the general law to the understanding.

THE MOOD OF EXPOSITORY WRITING

There is still a third distinction of great importance between exposition and the other forms of writing. The various subjects of experience may be treated in two ways. We may consider them as at rest, as fixed in space, as spread out before us like a map—in short, as static. Or we may regard them as living, growing, developing—in short, as dynamic. This difference may be made clearer by taking as an example a tree and supposing it the subject of our writing. We may regard the tree as fixed in space so that in our writing we may pass from point to point or take it up a part at a time. This is to treat the tree statically. Or we may think of the tree as growing, developing; we may be interested chiefly in showing its stages of growth, and the like. This is to write about the tree dynamically.

From the difference between static and dynamic treatment, we may distinguish again two large divisions of writing. The dynamic mode is characteristic of narrative and argument. In narrative we either show the individual object as growing and developing, or we display a given event as a succession of particulars and details having movement. In argument the procedure is likewise essentially dynamic. The conclusion we wish the reader to accept is made to come into being in the course of the argument—to grow, so to speak, from its elements—the facts and principles with which we start. The static mode is characteristic of description and exposition. In description, we treat the object we are writing about as spread out before

us while we pass from point to point in our examination. In exposition, the subject-matter—the general truth underlying an idea or group of ideas—is, so to speak, spread out before the mind and a map made of it. It is carefully bounded by the process known technically as definition, it is separated into its parts by division; finally each part of the idea is set before the reader with adequate development Such a conception of a static view of the idea to be expounded is, as Professor Gardiner has pointed out in his *The Forms of Prose Literature*, inherent in the signification of the terms we employ to designate this form of writing. "The natural figure of speech which you use is this figure of *seeing*. It is a noticeable fact, moreover, that the words which have to do with explanation spring from just this same sense of a clear and lucid view of the subject. *Exposition* is a setting forth, as one arranges cards in a game of solitaire; *explanation* is a making plain or smoothing out; *perspicuous* springs from the figure of 'seeing through.' These etymological facts have deep suggestiveness for anybody who is going to make explanations."[1]

From this static treatment of its material comes the typical mood of exposition. It appears that we instinctively care more for living than for dead things, for motion than for rest, for evolution than for arrested development, and from this perhaps springs the general fact that a dynamic treatment invites the author to greater or less display in his writing of his feelings. Whether the explanation hazarded for this fact be true or not, it seems to be generally true of both the forms of writing that have typically the dynamic mode of treatment—narrative and argument—that they are more or less subjective in mood. On the other hand, the static mode of treatment is essentially dispassionate and unbiassed. This objective and uncontroversial tone is eminently characteristic of both description and exposition.

Although expository writing is characterized by impartiality of treatment, we must not understand this as implying that

[1] *The Forms of Prose Literature*, p. 27.

"exposition must be bare, cold, impersonal. Bare, cold, impersonal it may be, indeed, and still worthy; as in a text-book of physics; but it need not be, and in such expository essays as most of us write, it should not be. For a listless reader will not take pains to understand; and, on the other side, the significance of a subject will be the more readily found by the writer for whom that significance has some real interest. So, in detail, the abundance of example and illustrations which makes Macaulay's essays popular is a direct means of clearness. Else the same means would not be so freely used by Huxley also, and by Tyndall, and proverbially by the most effective teachers and preachers. In this and in other ways the transpiring of the writer's personality makes the exposition better. The only caution necessary is not to forget the prime object which is to reach significant generalizations and to reach them clearly."[1]

SUMMARY

Concluding what has been said about the nature of exposition, we may succinctly define exposition as *that kind of writing which has as its primary function the impartial unfolding of any phenomenon, hypothesis or generalization to the understanding of the reader.*

II

KINDS OF EXPOSITION

Since the motive common to all exposition is the desire to explain something to the reader, it is evident that this form of writing is not only of exceeding great practical value, but is very extended in its range of subjects. As we have seen, without exposition we might know and communicate to others the particulars of our experience; but the meaning of those particulars, the general principles that underlie them, could not be definitely set forth. From the small matters of daily life

[1] Baldwin's *A College Manual of Rhetoric*, p. 38.

and experience, up to handing on the torch of knowledge from one generation to the next, and so making progress and civilization possible, exposition is everywhere called into use.

According to method and purpose, two kinds of expository writing may be distinguished, which we may call, for want of more exact designations, *scientific* exposition, and *familiar* exposition. In scientific exposition, the writer selects a subject within his powers, states it clearly and accurately, gathers material by careful thinking and reading, and develops it into a serious, thorough, and sustained piece of explanation. The writings of Macaulay, Huxley, Bryce, Tyndall, Mill, Spencer, Newman, are examples of this type of exposition showing its severity of method and careful accuracy.

Familiar exposition, on the other hand, is generally looser in structure and aims to give the personal impressions of the writer, his whims and fancies, in a manner resembling the easy confidential tone of conversation. The subjects chosen are usually of a light character, and an original point of view is not infrequently presented. The essays of Charles Lamb, Steele, Addison, Thackeray, and Stevenson are illustrations of this type of exposition. It was this looser type of exposition which first gave vogue to the term *essay*, but the development of this form of literature has been so markedly away from a subjective, personal, and leisurely discussion towards an objective, concentrated, and unemotional method, that when we hear the word *essay* to-day we think rather of the scientific exposition than the familiar.

III

ESSENTIALS OF EXPOSITORY WRITING

A COMPLETE discussion of the essentials of exposition is far too extensive and exhaustive for treatment in this introduction. Furthermore, as the studies forming the body of this book acquaint the student with the more important of the

processes and problems of expository writing, it is unnecessary to repeat them here. This introductory discussion will, therefore, merely confine itself to a few of the requisites of clear and forcible exposition which the student should have in mind from the outset of his study.

FULNESS OF INFORMATION

The first qualification for successful exposition is clear and adequate knowledge of the subject to be discussed. The masters of expository writing always impress those who hear them or read them with the evident thoroughness with which they have thought all the vagueness and obscurity out of their subjects. Such was notably the case with Tyndall, and Huxley writes of him that "whatever subject he took up he never rested until he had attained a clear conception of all the conditions and processes involved, or had satisfied himself that it was not attainable. And in dealing with physical problems, I really think that he in a manner saw the atoms and molecules, and felt their pushes and pulls. . . . The quality of active veracity, the striving for knowledge as apart from hearsay, lay at the very root of Tyndall's very remarkable powers of exposition."[1]

A writer who has cultivated the habit of seeking clearness of thought will not be content with hasty or ill-considered work. Neither will he find himself willing to attempt subjects that are beyond his abilities, but will keep the selection of subjects within the sphere of his actual experience and definite knowledge. There is no excuse for a writer's not having the habit of seeking clearness of knowledge, for it is obtainable, as Huxley says, by any "one who possesses a tolerably clear head and a decent conscience and who is willing to give himself the necessary trouble."

KEEPING THE READER BEFORE THE IMAGINATION

A second important qualification of the expository writer is the ability to keep the reader before his imagination. The

[1] *Nineteenth Century*, Vol. XXV, p. 4.

following quotation from Palmer's *Self-cultivation in English* is suggestive of what is incumbent upon the writer in adapting his explanation to the habits of thought, the tastes and aptitudes of the reader:

"Every utterance really concerns two. Its aim is social. Its object is communication; and while unquestionably prompted half-way by the desire to ease our mind through self-expression, it still finds its only justification in the advantage somebody else will draw from what is said. Speaking or writing is, therefore, everywhere a double-ended process. It springs from me, it penetrates him; and both of these ends need watching. Is what I say precisely what I mean? That is an important question. Is what I say so shaped that it can be readily assimilated by him who hears? This is a question of quite as great consequence, and much more likely to be forgotten. . . . As I write, I must unceasingly study what is the line of least intellectual resistance along which my thought may enter the differently constituted mind; and that line I must subtly adjust, without enfeebling my meaning. Will this combination of words or that make the meaning clear? Will this order of presentation facilitate swiftness of apprehension, or will it clog the movement? What temperamental perversities in me must be set aside in order to render my reader's approach to what I tell him pleasant? What temperamental perversities in him must be accepted by me as fixed facts, conditioning all I say? These are the questions the skilful writer is always asking."[1]

SELECTION OF MATERIAL

Passing from the qualifications of the writer to considerations of structure, that is, the organization of the exposition into a coherent and inter-related whole, we find first that the success of an exposition is largely dependent upon the proper selection of material. From whatever source knowledge of the subject is obtained—whether from personal observation and experience or from reading—it should be abundant and comprehensive in order that only the fittest may be used. In making selection

[1] *Self-cultivation in English*, p. 24.

of what is to be used, the principle should be to omit all that is not necessary while at the same time retaining all that is essential. Unnecessary material is to be omitted because its presence will tend to obscure what is essential and vital. On the other hand, no idea indispensable to the complete discussion of the subject can be omitted. Evidently, the proper selection of material is a relative matter depending largely upon the reader for whom the exposition is intended, and his intelligence and general knowledge should be taken as a practical guide in this matter.

CLEAR ARRANGEMENT

Another important structural problem connected with effective exposition is clear arrangement. This we may consider under the two aspects of logical progress and obvious structure. The most important of these two aspects is perhaps logical progress. The exposition must not mark time; it must march forward toward some goal, some definite conclusion. "An exposition is no mere fortuitous concourse of ideas; it is a careful record of the mind's activity when exercised in a single direction."[1] Hence there is implied in good exposition the idea of progress. Furthermore, this progress must be logical. In narration and description, the subject itself imposes, or, at least, pretty clearly indicates, the order of treatment—especially in narrative when the chronological order is to be followed. This, however, is not the case with exposition. In no other species of writing is good arrangement more necessary, and yet in no other species of writing can so few definite rules of arrangement be given. Of this much, however, the student may be certain: his ideas must not be set down at random; there must be evident a clearly conceived plan chosen not at haphazard, but with reference to economical and attractive presentation to the reader. "Given a certain series of ideas," says Professor Minto, "to be passed from one mind to another, bit by bit, unit by unit, as a crowd passes one by one through a narrow opening, there must be one order better than another. A

[1] Scott and Denney's *Paragraph Writing*, third edition, p. 95.

theatre can be emptied more quickly by a good arrangement than if the matter is left to chance. And in writing, the problem is still more difficult than emptying a theatre, or a bottle of water. You have to get your water out of one narrow-necked bottle into another, spilling as little as possible by the way."[1]

There are several common schemes of arrangement that serve frequently as helpful guides because they are based upon habits of thinking that govern normal minds, such as, for instance, going from the known to the unknown, or arranging the divisions of a subject upon the basis of similarity or contrast, or utilizing the principle of climax by proceeding from the less to the more important. But none of these arrangements should be accepted mechanically. Every piece of exposition has its own particular problems of arrangement and each case must be considered separately. For the special case, the best order will be that method of arrangement which stands the test, Is this order one that gives the reader at each step in the development the maximum of understanding and the minimum of bewilderment as to the subject matter and as to the reason for the order of presentation?

The second phase of clear arrangement—obvious structure—requires that the progress of thought be by definitely marked steps. Here again exposition differs from narrative and description. In the case of these two kinds of writing, although there must be a definitely planned arrangement in the mind of the writer, it is as a rule needless and clumsy to state it to the reader. In exposition, on the contrary, the plan must be made evident to the reader. As the exposition passes from head to head of the discussion, the reader must be definitely and unmistakably informed by means of transition links and by summaries just where fall the dividing lines between topics. It is sometimes advisable to set forth the plan of the whole composition near the beginning of the discussion; but ordinarily it is sufficient simply to have enough of the plan explained at the start so that the reader may begin intelligently, and the rest indicated at the proper places either by suggestion or explicit statement.

[1] Bainton's *Art of Authorship*, p. 237.

The value of this quality of obvious structure Benjamin Jowett of Oxford, the noted English scholar and educator, tersely emphasized in the sentence, "Connection is the soul of good writing." Professor Genung says on this point, "The problem of transition—how to make one stage of thought pass naturally into the next—is always present in literary composition, and is especially to be satisfied between the main divisions."[1] Professor Genung also has this to say of the difference between young writers and more experienced ones in their attitude toward the indication of structure in their writings. "Such indications of structure are elements of discourse in which we find increasing care and copiousness as writers gain more experience of the interpretating capacities of their readers. Young writers are too apt to neglect them, and their work becomes blind and vague in consequence. Older writers see better the helpfulness and are less sensitive to the formality of laying out their thoughts as thoroughly as may be useful for clearness and definiteness."[2]

PARAGRAPHING AS AN INDICATION OF STRUCTURE

Obvious structure necessarily involves careful paragraphing. In following the course of general and abstract thought such as we commonly find in exposition, the mind wearies much more quickly than in following descriptions and narratives. It is important that there should be halting places—points indicated where the reader may feel that a certain distinct stage of the exposition has been completed, where he may take breath, so to speak, before passing on to another. Hence judicious paragraphing is an important element in successful exposition. The paragraphic divisions should not be arbitrary nor accidental, but should correspond to some natural and logical grouping of thought. Each paragraph should contain only such material as is logically justifiable as a unit by itself. The fundamental principle of the inner structure of the paragraph is therefore unity. It must have one central thought to which all the ideas and facts making up the development of the para-

[1] *Working Principles of Rhetoric*, p. 457.
[2] *Practical Elements of Rhetoric*, p. 284.

graph shall be properly subordinated. The question of long or short paragraphs must be determined largely by the capacity of the reader. If he lacks the power of grasping large and complicated wholes, the tendency of the paragraphs had better be towards shortness; if, on the other hand, the readers have this power, the paragraphs may with advantage be much longer, for such a reader would probably find short paragraphs jerky, confusing, and ineffective.

MEANS OF AMPLIFICATION

The third matter we shall consider in connection with the study of principles of structure is that of amplification, or the adequate development of the subject. In order for an idea to be clearly understood it is necessary for it to have *body*. "Time must be given," says De Quincey, "for the intellect to eddy about a truth, and to appropriate its bearings. There is a sort of previous lubrication, such as the boa-constrictor applies to any subject of digestion, which is requisite to familiarize the mind with a startling or complex novelty."[1] It is therefore upon appropriate development that we must depend if our thought is to fulfil its destined mission in the reader's mind. It is of course impossible to indicate all methods of development. Mention therefore will only be made of that method of amplification most helpful in expository writing—reducing generals to particulars.

As we have seen, exposition deals largely with the abstract and the general. The full meaning of the general and the abstract is usually not clear, and clearness is the *sine qua non* of expository writing. Hence the writer must take pains to avoid excessive abstraction by giving the specific details upon which his generalizations are based. General facts must be amplified by enumeration of particulars enough to make conclusive ground for the assertion of it; general principles must be amplified by instances and examples in order to make clear the character of them. It is a good rule for expository writing, and one that the young writer will do well to adopt literally,

[1] *Essay on Style*, Part I.

to follow every general statement with particulars and details, with specific examples or concrete illustrations, or comparisons and analogies with what is known and familiar. "Abstractions produce little or no effect until translated into concrete terms," says Lamont. "If the writer does not translate them the reader must; and this task makes hard reading."[1] Concreteness, therefore, is very important in expository writing both for clearness and interest.

We have seen how on the structural side successful exposition is dependent upon careful selection of material, its clear arrangement and adequate amplification. We must now turn to details of expression, or, as it is commonly called, style. The term style refers to two distinct things—first, the choice of suitable words, and second, the best method of combining and arranging these words into such larger elements of composition as phrases, clauses, and sentences.[2]

CHOICE OF WORDS

Since the fundamental aim in expository writing is that the writer shall make himself clear to the reader with the least possible extra effort on the latter's part,[3] the primary requisite of style is therefore clearness or lucidity. "Lucidity—*lucidity*, that is the word, clear as the open daylight from beginning to end. Unless the idea is as plain and palpable, as real in the print as are the trees in the field or the men in the street, the work is faulty"—so writes the naturalist, John Burroughs.[4]

Such clearness is largely dependent upon the accurate choice of words. "Obviously good English is exact English," says Professor Palmer. . . . The first business of every man who

[1] *Specimens of Exposition*, p. 20.

[2] Since so many matters of style relate to general composition, only a few important principles bearing directly upon success in expository writing are considered in this Introduction. The student who wishes further information should seek it in some standard rhetoric.

[3] This statement is based upon Spencer's Principle of Economy of Attention. The student should seek fuller acquaintance with this important principle by reading the *Essay on Style*.

[4] Bainton's *Art of Authorship*, p. 234.

would train himself in language is to articulate his thought, to know definitely what he wishes to say, and then to pick those words which compel the hearer to think of this and only this."[1] Huxley also urges clearness of expression, saying, "I have learned to spare no labour upon the process of acquiring clear ideas—to think nothing of writing a page four or five times over if nothing else will bring the words which express all I mean and nothing more than I mean."

In seeking accuracy of expression the writer of exposition must be on his guard especially against the ambiguity of general terms. The nature of exposition makes such words necessary enough to the discussion, but it is well to use them only after they have been so defined as to place specific limitations upon them. The danger to loose use which lurks in such general words as *function*, *development*, *democratic*, *classical*, *species*, and the like may be avoided by fixing them by definitions which answer the following tests: 1. Does it cover all the specific facts for which it is used? 2. Does it exclude all other facts? and 3. Does it in itself contain terms which cannot be understood by any rational reader?[2]

"In practice use general terms in exposition when they will sum up a long process of thought in a single phrase, and will make your reader see the subject swiftly and immediately; but in using them remember always that they are treacherous; that they carry so many ulterior implications both of thought and feeling, that you yourself may be led astray in using them; and, moreover, that they put you at the mercy of careless readers"—such is the advice of Professor Gardiner in regard to general terms.[3]

TECHNICAL TERMS

Accuracy of expression is often gained by the use of technical terms. Technical terms having less vagueness than general or popular terms are more exact and definite in their logical mean-

[1] *Self-Cultivation in English*, p. 12.
[2] Adapted from Gardiner's *The Forms of Prose Literature*, p. 50.
[3] *The Forms of Prose Literature*, p. 51.

ing—their denotation, as it is called in rhetoric. To use technical terms is entirely permissible—it is even more economical ordinarily, in writing intended to be read by experts and specialists. But in writing intended for general readers, they should be used cautiously. Under such conditions their use should be regulated by the following principles:

"In technical writing, technical forms should be used as freely as the subject permits, but it should be remembered that while a technical term has for those familiar with it an exact and definite meaning, it has no meaning at all, or a meaning which is incomplete and inexact for those to whom it has not been defined. Consequently the writer *needs to define every technical term* which he does not feel safe in assuming the reader already knows in its exact usage. The success of a writer on a technical subject depends largely upon the skill he shows in deciding what terms he may use without definition, and in defining all others."[1]

Conciseness is another quality to be sought in the selection of words. "The fewer the words the more pungent the expression. Brevity is the soul not simply of a jest, but of wit in its finest sense where it is identical with wisdom."[2] Unnecessary fulness of expression makes it harder for the reader to get the writer's meaning, either because too many words in proportion to the ideas destroy interest and lull the attention to sleep, or because too many ideas distract and confuse the reader. Occasionally fulness of expression may be dictated by the necessity of keeping a thought a little longer before the reader's mind, and thus preventing him from hurrying on to the next while this one was imperfectly understood, but, on the whole, Huxley was not far wrong in regarding "verbosity as the deadliest and most degrading of literary sins."

One frequent cause of unnecessary words is the careless adoption of sentence structure which is faulty or which entails the use of needless circumlocutions. If the student forms the habit of writing no part of a sentence in its final form until the

[1] Earle's *The Theory and Practice of Technical Writing*, p. 206.
[2] Palmer's *Self-cultivation in English*, p. 13.

whole has been framed in his mind, and of choosing always the simplest construction that will express the facts, he will not only guard himself from the use of unnecessary words, but also improve in other ways the structure of his sentences.

STRUCTURE OF SENTENCES

The closing statement of the preceding paragraph naturally brings us to a discussion of the sentence and its structure in clear and economical expression. The first rule of the sentence is that it should express a thought which is felt as a whole. However long or complex the sentence may be, it will embody but one central thought. We may analyze it and discover coördinate and subordinate ideas, but what makes it a good sentence is the fact that taken together it is a unit. No arbitrary rules can be laid down with regard to the length or complexity of sentences. Provided the writer can make the sentence convey to the reader an impression of oneness, he has complied with all requirements. As Sir Arthur Helps has said, "The style that deals in long sentences or short sentences . . . is a bad style." So far as unity is concerned it is unnecessary to distinguish between the two kinds. A very long and loose sentence may be so constructed as to embody one definite and rounded conception. A moderately short sentence may make upon the reader only a vague and confused impression. Almost the only practical rules for sentence making are Bain's, "Choose the larger breaks in sense;" and Minto's, "Beware of distracting from the effect of the main statement by particulars not immediately relevant."

A common cause of poor sentences is the writer's failure to indicate the proper subordination of the several related ideas. Generally this arises from the overuse of coördinating conjunctions and the consequent frequency of the compound type of sentence. By taking advantage of the plentiful supply of devices in English for indicating various shades of relationship, the writer can convert these improper compound sentences into complex sentences that really represent the relationship

of the thoughts grouped together and which makes a stronger impression of unity.

Sentences are made clear by giving the most important parts the emphatic positions. The beginning of the sentence is a place of emphasis and should be occupied by an important idea. But the conclusion is an even more emphatic position, because the close of the sentence is the point where the reader grasps the meaning of what he reads completely. Bain well describes the principle of sentence emphasis as follows: "As, in an army on the march, the fighting columns are placed front and rear, and the baggage in the centre, so the emphatic parts of a sentence should be found either in the beginning or in the end, subordinate and matter of fact expressions in the middle." By its structure the periodic sentence tends to concentrate emphasis properly, and its use should therefore be cultivated but not to the extent of giving an air of unnaturalness to one's style.

Variety in the structure of the sentence is another important matter. We find in the best writers a constant variation which secures the important aid of novelty. The reader's attention is aroused at every turn by some new arrangement of clause, different length or complexity of sentence, change in the places of stress, and the like. A brief, simple, direct sentence will be followed by a slightly more complex one, and this by another in which involution of subordinate clauses is carried to considerable degree. It is important to note that when this variety is at its best it is not a mere haphazard avoidance of monotony, but a variety in unity. The differences between the various elements of the successive sentences find their explanation in differences in the writer's process of thought. One sentence is longer or shorter than another because the thought demanded that it should be.

SINCERITY THE CARDINAL QUALITY OF STYLE

Since the rounded and idealized thought of sentence, paragraph, and whole exposition is individual, that is, it is nothing but the writer's mind acting in a certain definite way, it fol-

lows that fundamentally style is the expression of personality. The word style is sometimes used in a narrower sense than this, as an equivalent for a manner of expression independent of the subject-matter.[1] But in such a sense, the writer of exposition has little use for the cultivation of style. In the best writing expression and thought are not to be divided. It is not until we see a personality looming up behind or in the lines of a piece of writing—in poem, essay, scientific exposition, technical treatise, or what not—that we can assert that it has any style at all. When the warm living personality of the writer emerges from his writing with such vividness and inevitableness that we are not made aware of the means by which it is brought to our attention, then we have style in its primary and ultimate meaning. In such a use of the word it is true, as Professor Gardiner says, that "the power of pure style is not to be neglected by any one who is writing an exposition."[2]

Writing that is the expression of the writer's personality possesses the paramount quality of sincerity. "In all sincere speech there is power, not necessarily great power, but as much as the speaker is capable of. Speak for yourself and from yourself or be silent. It can be of no good that you should tell in your 'clever' feeble way what another has already told us with the dynamic energy of conviction. If you can tell us something that your own eyes have seen, your own mind has thought, your own heart has felt, you will have power over us, and all the real power that is possible for you. If what you have seen is trivial, if what you have thought is erroneous, if what you have felt is feeble, it would assuredly be better that you should not speak at all; but if you insist of speaking Sincerity will secure the uttermost of power."[3]

The writer's duty always to be sincere is thus put by Walter Pater, one of the most finished writers of English prose in the nineteenth century. "It would take me a long time to formulate the rules, conscious or unconscious, which I have followed

[1] See the selection from Newman in this book, p. 108.
[2] *The Forms of Prose Literature*, p. 58.
[3] Lewes' *Principles of Success in Literature*, edited by F. N. Scott, p. 91.

in my humble way in my writing. I think they would one and all be reducible to *truthfulness*—truthfulness, I mean, to one's own inward view of impression. It seems to me that all the excellencies of composition, clearness, subtlety, beauty, freedom, severity, and any other there may be, depend upon the exact propriety with which language follows or shapes itself to the consciousness within. True and good elaboration of style would, in this way, come to be the elaboration, the articulation to oneself of one's own meaning, one's real condition of mind. I suppose this is the true significance of that often quoted saying, that style is the man."[1]

The whole doctrine of style may, in concluding, be summed up briefly in the words of Professor John Earle, "He who would write with anything worthy to be called style must first grow thoughts which are worth communicating, and then he must deliver them in his own natural language."[2]

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[1] Bainton's *Art of Authorship*, p. 293.
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PART I

SELECTIONS ILLUSTRATING GENERAL PRINCIPLES OF COMPOSITION IN THEIR RELATION TO EXPOSITION

THE EXPOSITION AS AN ORGANIC STRUCTURE

THE IMPORTANCE OF DUST[1]

ALFRED RUSSEL WALLACE

THE majority of persons, if asked whât were the uses of dust, would reply that they did not know it had any, but they were sure it was a great nuisance. It is true that dust, in our towns and in our houses is often not only a nuisance, but a serious source of disease; while in many countries it produces ophthalmia, often resulting in total blindness. Dust, however, as it is usually perceived by us, is, like dirt, only matter in the wrong place, and whatever injurious or disagreeable effects it produces are largely duc to our own dealings with nature. So soon as we dispense with horse-power and adopt purely mechanical means of traction and conveyance, we can almost wholly abolish disease-bearing dust from our streets, and ultimately from all our highways; while another kind of dust, that caused by the imperfect combustion of coal, may be got rid of with equal facility so soon as we consider pure air, sunlight, and natural beauty to be of more importance to the population as a whole than are the prejudices or the vested interests of those who produce the smoke.

But though we can thus minimize the dangers and the inconveniences arising from the grosser forms of dust, we cannot wholly abolish it; and it is, indeed, fortunate we cannot do so, since it has now been discovered that it is to the presence of dust we owe much of the beauty, and perhaps even the very habit-

[1] Reprinted from Chapter IX of *The Wonderful Century* (Dodd, Mead & Co.).

ability, of the earth we live upon. Few of the fairy tales of science are more marvellous than these recent discoveries as to the varied effects and important uses of dust in the economy of nature.

The question why the sky and the deep ocean are both blue did not much concern the earlier physicists. It was thought to be the natural color of pure air and water, so pale as not to be visible when small quantities were seen, and only exhibiting its true tint when we looked through great depths of atmosphere or of organic water. But this theory did not explain the familiar facts of the gorgeous tints seen at sunset and sunrise, not only in the atmosphere and on the clouds near the horizon, but also in equally resplendent hues when the invisible sun shines upon Alpine peaks and snowfields. A true theory should explain all these colors, which comprise almost every tint of the rainbow.

The explanation was found through experiments on the visibility or non-visibility of air, which were made by the late Professor Tyndall about the year 1868. Everyone has seen the floating dust in a sunbeam when sunshine enters a partially darkened room; but it is not generally known that if there was absolutely no dust in the air the path of the sunbeam would be totally black and invisible, while if only very little dust was present in very minute particles the air would be as blue as a summer sky.

This was proved by passing a ray of electric light lengthways through a long glass cylinder filled with air of varying degrees of purity as regards dust. In the air of an ordinary room, however clean and well ventilated, the interior of the cylinder appears brilliantly illuminated. But if the cylinder is exhausted and then filled with air which has passed slowly through a fine gauze of intensely heated platinum wire, so as to burn up all the floating dust particles, which are mainly organic, the light will pass through the cylinder without illuminating the interior, which, viewed laterally, will appear as if filled with a dense black cloud. If, now, more air is passed into the cylinder through the heated gauze, but so rapidly that the dust particles are not wholly consumed, a slight blue haze will

begin to appear, which will gradually become a pure blue, equal to that of a summer sky. If more and more dust particles are allowed to enter, the blue becomes paler, and gradually changes to the colorless illumination of the ordinary air.

The explanation of these phenomena is that the number of dust particles in ordinary air is so great that they reflect abundance of light of all wave-lengths, and thus cause the interior of the vessel containing them to appear illuminated with white light. The air which has passed slowly over white-hot platinum has had the dust particles destroyed, thus showing that they were almost wholly of organic origin, which is also indicated by their extreme lightness, causing them to float permanently in the atmosphere. The dust being thus got rid of, and pure air being entirely transparent, there is nothing in the cylinder to reflect the light which is sent through its centre in a beam of parallel rays, so that none of it strikes against the sides; hence the inside of the cylinder appears absolutely dark. But when all the larger dust particles are wholly or partially burnt, so that only the very smallest fragments remain, a blue light appears, because these are so minute as to reflect chiefly the more refrangible rays, which are of shorter wave-length—those at the blue end of the spectrum, which are thus scattered in all directions, while the red and yellow rays pass straight on as before.

We have seen that the air near the earth's surface is full of rather coarse particles which reflect all the rays, and which therefore produce no one color. But higher up the particles necessarily become smaller and smaller, since the comparatively rare atmosphere will only support the very smallest and lightest. These exist throughout a great thickness of air, perhaps from one mile to ten miles high or even more, and blue or violet rays being reflected from the innumerable particles in this great mass of air, which is nearly uniform in all parts of the world as regards the presence of minute dust particles, produces the constant and nearly uniform tint we call sky-blue. A certain amount of white or yellow light is no doubt reflected from the coarser dust in the lower atmosphere, and slightly dilutes the blue and

renders it not quite so deep and pure as it otherwise would be. This is shown by the increasing depth of the sky-color when seen from the tops of lofty mountains, while from the still greater heights attained in balloons the sky appears of a blue-black color, the blue reflected from the comparatively small amount of dust particles being seen against the intense black of stellar space. It is for the same reason that the "Italian skies" are of so rich a blue, because the Mediterranean Sea on one side and the snowy Alps on the other do not furnish so large a quantity of atmospheric dust in the lower strata of air as in less favorably situated countries, thus leaving the blue reflected by the more uniformly distributed fine dust of the higher strata undiluted. But these Mediterranean skies are surpassed by those of the central Pacific Ocean, where, owing to the small area of land, the lower atmosphere is more free from coarse dust than any other part of the world.

If we look at the sky on a perfectly fine summer's day, we shall find that the blue color is the most pure and intense overhead, and when looking high up in a direction opposite to the sun. Near the horizon it is always less bright, while in the region immediately round the sun it is more or less yellow. The reason of this is that near the horizon we look through a very great thickness of the lower atmosphere, which is full of the larger dust particles reflecting white light, and this dilutes the pure blue of the higher atmosphere seen beyond. And in the vicinity of the sun a good deal of the blue light is reflected back into space by the finer dust, thus giving a yellowish tinge to that which reaches us reflected chiefly from the coarse dust of the lower atmosphere. At sunset and sunrise, however, this last effect is greatly intensified, owing to the great thickness of the strata of air through which the light reaches us. The enormous amount of this dust is well shown by the fact that, then only, we can look full at the sun, even when the whole sky is free from clouds and there is no apparent mist. But the sun's rays then reach us after having passed, first, through an enormous thickness of the higher strata of the air, the minute dust of which reflects most of the blue rays away from us,

leaving the complementary yellow light to pass on. Then, the somewhat coarser dust reflects the green rays, leaving a more orange colored light to pass on; and finally some of the yellow is reflected, leaving almost pure red. But owing to the constant presence of air currents, arranging both the dust and vapor in strata of varying extent and density, and of high or low clouds, which both absorb and reflect the light in varying degrees, we see produced all those wondrous combinations of tints and those gorgeous ever-changing colors, which are a constant source of admiration and delight to all who have the advantage of an uninterrupted view to the west, and who are accustomed to watch for these not unfrequent exhibitions of nature's kaleidoscopic color-painting. With every change in the altitude of the sun the display changes its character; and most of all when it has sunk below the horizon, and, owing to the more favorable angles, a larger quantity of the colored light is reflected toward us. Especially when there is a certain amount of cloud is this the case. These, so long as the sun was above the horizon, intercepted much of the light and color; but, when the great luminary has passed away from our direct vision, his light shines more directly on the under sides of all the clouds and air strata of different densities; a new and more brilliant light flushes the western sky, and a display of gorgeous ever-changing tints occurs which are at once the delight of the beholder and the despair of the artist. And all this unsurpassable glory we owe to—dust!

A remarkable confirmation of this theory was given during the two or three years after the great eruption of Krakatoa, near Java. The volcanic *débris* was shot up from the crater many miles high, and the heavier portion of it fell upon the sea for several hundred miles around, and was found to be mainly composed of very thin flakes of volcanic glass. Much of this was of course ground to impalpable dust by the violence of the discharge, and was carried up to a height of many miles. Here it was caught by the return current of air continually flowing northward and southward above the equatorial zone; and as these currents reached the temperate zone where the surface

rotation of the earth is less rapid they continually flowed eastward, and the fine dust was thus carried at a great altitude completely round the earth. Its effects were traced some months after the eruption in the appearance of brilliant sunset glows of an exceptional character, often flushing with crimson the whole western half of the visible sky. These glows continued in diminishing splendor for about three years, they were seen all over the temperate zone, and it was calculated that, before they finally disappeared, some of this fine dust must have travelled three times round the globe.

The same principle is thought to explain the exquisite blue color of the deep seas and oceans and of many lakes and springs. Absolutely pure water, like pure air, is colorless, but all seas and lakes, however clear and translucent, contain abundance of very finely divided matter, organic or inorganic, which, as in the atmosphere, reflects the blue rays in such quantity as to overpower the white or colored light reflected from the fewer and more rapidly sinking particles of larger size. The oceanic dust is derived from many sources. Minute organisms are constantly dying near the surface, and their skeletons, or fragments of them, fall slowly to the bottom. The mud brought down by rivers, though it cannot be traced on the ocean floor more than about 150 miles from land, yet no doubt furnishes many particles of organic matter which are carried by surface currents to enormous distances and are ultimately dissolved before they reach the bottom. A more important source of finely divided matter is to be found in volcanic dust which, as in the case of Krakatoa, may remain for years in the atmosphere, but which must ultimately fall upon the surface of the earth and ocean. This can be traced in all the deep-sea oozes. Finally there is meteoric dust, which is continually falling to the surface of the earth, but in such minute quantities and in such a finely-divided state that it can only be detected in the oozes of the deepest oceans, where both inorganic and organic *débris* is almost absent.

The blue of the ocean varies in different parts from a pure blue somewhat lighter than that of the sky, as seen about the

northern tropic in the Atlantic, to a deep indigo tint, as seen in the north temperate portions of the same ocean: due, probably, to differences in the nature, quantity, and distribution of the solid matter which causes the color. The Mediterranean, and the deeper Swiss lakes are also blue of various tints, due also to the presence of suspended matter, which Professor Tyndall thought might be so fine that it would require ages of quiet subsidence to reach the bottom. All the evidence goes to show, therefore, that the exquisite blue tints of sky and ocean, as well as all the sunset hues of sky and cloud, of mountain peak and alpine snows, are due to the finer particles of that very dust which, in its coarser forms, we find so annoying and even dangerous.

But if this production of color and beauty were the only useful function of dust, some persons might be disposed to dispense with it in order to escape its less agreeable effects. It has, however, been recently discovered that dust has another part to play in nature; a part so important that it is doubtful whether we could even live without it. To the presence of dust in the higher atmosphere we owe the formation of mists, clouds, and gentle beneficial rains, instead of waterspouts and destructive torrents.

It is barely twenty years ago since the discovery was made, first in France by Coulier and Mascart, but more thoroughly worked out by Mr. John Aitken in 1880. He found that if a jet of steam is admitted into two large glass receivers,—one filled with ordinary air, the other with air which has been filtered through cotton wool so as to keep back all particles of solid matter,—the first will be instantly filled with condensed vapor in the usual cloudy form, while the other vessel will remain quite transparent. Another experiment was made, more nearly reproducing what occurs in nature. Some water was placed in the two vessels prepared as before. When the water had evaporated sufficiently to saturate the air the vessels were slightly cooled, when a dense cloud was at once formed in the one while the other remained quite clear. These experiments,

and many others, showed that the mere cooling of vapor in air will not condense it into mist clouds or rain, unless *particles of solid matter* are present to form *nuclei* upon which condensation can begin. The density of the cloud is proportionate to the number of the particles; hence the fact that the steam issuing from the safety-valve or the chimney of a locomotive forms a dense white cloud shows that the air is really full of dust particles, most of which are microscopic but none the less serving as centres of condensation for the vapor. Hence, if there were no dust in the air, escaping steam would remain invisible; there would be no clouds in the sky; and the vapor in the atmosphere, constantly accumulating through evaporation from seas and oceans and from the earth's surface, would have to find some other means of returning to its source.

One of these modes would be the deposition of dew, which is itself an illustration of the principle that vapor requires solid or liquid surfaces to condense upon; hence dew forms more readily and more abundantly on grass, on account of the numerous centres of condensation it affords. Dew, however, is now formed only on clear cold nights after warm or moist days. The air near the surface is warm and contains much vapor, though below the point of saturation. But the innumerable points and extensive surfaces of grass radiate heat quickly, and becoming cool, lower the temperature of the adjacent air, which then reaches saturation point and condenses the contained vapor on the grass. Hence, if the atmosphere at the earth's surface became super-saturated with aqueous vapor, dew would be continuously deposited, especially on every form of vegetation, the result being that everything, including our clothing, would be constantly dripping wet. If there were absolutely no particles of solid matter in the upper atmosphere, all the moisture would be returned to the earth in the form of dense mists, and frequent and copious dews, which in forests would form torrents of rain by the rapid condensation on the leaves. But if we suppose that solid particles were occasionally carried higher up through violent winds or tornadoes, then on those occasions the super-saturated atmosphere would condense

rapidly upon them, and while falling would gather almost all the moisture in the atmosphere in that locality, resulting in masses or sheets of water, which would be so ruinously destructive by the mere weight and impetus of their fall that it is doubtful whether they would not render the earth almost wholly uninhabitable.

The chief mode of discharging the atmospheric vapor in the absence of dust would, however, be by contact with the higher slopes of all mountain ranges. Atmospheric vapor, being lighter than air, would accumulate in enormous quantities in the upper strata of the atmosphere, which would be always super-saturated and ready to condense upon any solid or liquid surfaces. But the quantity of land comprised in the upper half of all the mountains of the world is a very small fraction of the total surface of the globe, and this would lead to very disastrous results. The air in contact with the higher mountain slopes would rapidly discharge its water, which would run down the mountain sides in torrents. This condensation on every side of the mountains would leave a partial vacuum which would set up currents from every direction to restore the equilibrium, thus bringing in more super-saturated air to suffer condensation and add its supply of water, again increasing the in-draught of more air. The result would be that winds would be constantly blowing toward every mountain range from all directions, keeping up the condensation and discharging, day and night and from one year's end to another, an amount of water equal to that which falls during the heaviest tropical rains. The whole of the rain that now falls over the whole surface of the earth and ocean, with the exception of a few desert areas, would then fall only on rather high mountains or steep isolated hills, tearing down their sides in huge torrents, cutting deep ravines, and rendering all growth of vegetation impossible. The mountains would therefore be so devastated as to be uninhabitable, and would be equally incapable of supporting either vegetable or animal life.

But this constant condensation on the mountains would probably check the deposit on the lowlands in the form of dew,

because the continual up-draught toward the higher slopes would withdraw almost the whole of the vapor as it rose from the oceans and other water-surfaces, and thus leave the lower strata over the plains almost or quite dry. And if this were the case there would be no vegetation, and therefore no animal life, on the plains and lowlands, which would thus be all arid deserts cut through by the great rivers formed by the meeting together of the innumerable torrents from the mountains.

Now, although it may not be possible to determine with perfect accuracy what would happen under the supposed condition of the atmosphere, it is certain that the total absence of dust would so fundamentally change the meteorology of our globe as, not improbably, to render it uninhabitable by man, and equally unsuitable for the larger portion of its existing animal and vegetable life.

Let us now briefly summarize what we owe to the universality of dust, and especially to that most finely divided portion of it which is constantly present in the atmosphere up to the height of many miles. First of all it gives us the pure blue of the sky, one of the most exquisitely beautiful colors in nature. It gives us also the glories of the sunset and the sunrise, and all those brilliant hues seen in high mountain regions. Half the beauty of the world would vanish with the absence of dust. But, what is far more important than the color of sky and beauty of sunset, dust gives us also diffused daylight, or skylight, that most equable, and soothing, and useful, of all illuminating agencies. Without dust the sky would appear absolutely black, and the stars would be visible even at noonday. The sky itself would therefore give us no light. We should have bright glaring sunlight or intensely dark shadows, with hardly any half-tones. From this cause alone the world would be so totally different from what it is that all vegetable and animal life would probably have developed into very different forms, and even our own organization would have been modified in order that we might enjoy life in a world of such harsh and violent contrasts.

In our houses we should have little light except when the

sun shone directly into them, and even then every spot out of its direct rays would be completely dark, except for light reflected from the walls. It would be necessary to have windows all round and the walls all white; and on the north side of every house a high white wall would have to be built to reflect the light and prevent that side from being in total darkness. Even then we should have to live in a perpetual glare, or shut out the sun altogether and use artificial light as being a far superior article.

Much more important would be the effects of a dust-free atmosphere in banishing clouds, or mist, or the "gentle rain of heaven," and in giving us in their place perpetual sunshine, desert lowlands, and mountains devastated by unceasing floods and raging torrents, so as, apparently, to render life all on the earth impossible.

QUESTIONS AND EXERCISES

The ideal of any well written composition has been aptly expressed by Pater in his *Essay on Style* as "that architectural conception of work which perceives the end in the beginning and never loses sight of it, and in every part is conscious of all the rest, till the last sentence does but, with undiminished vigor, unfold and justify the first." Pater means that every good composition must have its material carefully systematized and organized and all its parts skilfully adjusted to each other and to the whole. In other words, a composition is not a haphazard collection of miscellaneous ideas or observations, but an orderly presentation of thoughts, each of which is related to all of the others in a reasonable and necessary way, and all combining to make the meaning of the larger whole complete and satisfying. This idea of organization is brought out more fully in the following quotation from Ruskin, which, although originally written with reference to painting, is perfectly applicable to writing: "In a good composition," says he in *Two Paths*, "every idea is presented in just that order, and with just that force, which will perfectly connect it with all the other thoughts in the work, and will illustrate the others as well as receive illustration from them; so that the entire chain of thoughts offered to the beholder's mind shall be received by him with as much delight and with as little effort as possible. And thus you see design, properly so called, is human

invention, consulting human capacity. Out of the infinite heap of things around us in the world, it chooses a certain number which it can thoroughly grasp, and presents this group to the spectator in the form best calculated to enable him to grasp it also, and to grasp it with delight." More than two thousand years before Ruskin and Pater, Plato gave expression to practically the same idea about the construction of a composition, when he wrote: "Every discourse ought to be a living creature, having a body of its own and a head and feet; there should be a middle, a beginning, and end, adapted one to another and to the whole." Plato, Ruskin, and Pater all express the same idea—that a composition must have organic unity. From this fundamental law of the whole composition as an organic structure are derived the various rhetorical principles governing details of construction. These principles will now be studied in connection with the foregoing selection.

1. From what has been quoted above from Pater, it is evident that the first step towards good composition is to know exactly what one is trying to do. The best way to do this is to fix clearly in mind the subject of the composition, not vaguely in a phrase or clause, but definitely in a compact sentence. State the substance of this selection in a short, concise sentence.

2. The framing of such a guiding sentence at the outset helps in the second step towards successful composition, which is to stay by the main idea until it is developed so as to be thoroughly understood by the reader. To accomplish this there must be careful selection of material. The writer must not only reject the material that does not help in the development of his main thought, but he must also be careful to give full and adequate development to his thought. Test the writer's choice of material by asking, Has he introduced material at any point that does not bear directly on his main point, the presence of which tends to confuse the reader? Are any important matters bearing upon the subject entirely omitted? Does the writer seem to have stopped half-way in developing any part of his discussion?

3. After having secured by the process of selection those ideas and facts that justly belong to making clear the subject under discussion, the next consideration of the writer is the effective arrangement of this material into a connected whole. The precise method of arrangement in any given composition will, of course, depend upon the nature of the subject and the conditions under which it is treated, but method of some kind there must be. Carefully determine the

main points of this selection, writing them consecutively so that they will constitute a broad outline of the selection. Is the order of these the best for clearness and logic?

4. Not only must the topics of the composition be arranged in good order, but indication should be given the reader whenever one topic is finished and another taken up. One way of doing this is to shape every division of a composition so that the end of it will seem to suggest what is to follow. When this is impossible or undesirable, transition from one part to another may be made by means of some word, or phrase, or sentence of backward reference placed at or near the beginning of the new part. Find the important transitional and summarizing passages in this selection. Imagine these removed and endeavor to realize the consequent loss of clearness in seeing the dividing lines between the main topics.

5. The main point of the composition must not only be clear in the mind of the writer as a guide throughout; it must be given prominence in the composition, it must be properly emphasized. A writer may do this by announcing the subject himself at the beginning of the composition, or if he does not care to announce it there fully and explicitly, by foreshadowing or stating it in part. At what point near the beginning does Wallace make the reader aware of his subject? Has he given a full statement of his subject such as you formulated above in the subject-sentence? Another means of making clear the main thought of a composition is to end with an iteration of the point. Note how this is accomplished in this selection by a summary. Discuss the value of such a conclusion in refreshing the mind on things that have been discussed within the selection but which have begun to leave the memory. Are all the points of the preceding discussion embraced in the summary? Are any new points suggested? Would the summary have been more satisfactory if stated more briefly and concisely? On the whole, would you call this a strong conclusion, or could you suggest a better one?

6. The main thought of a composition is generally too extended to be discussed all at once, and it is generally divided by the writer into such parts as he can most clearly build up one by one into a connected whole. Not all of these parts bear with the same degree of directness or importance upon the complete development of the whole composition, and it is therefore necessary for the writer in his endeavor to make his composition a finished and symmetrical structure, with no part given undue emphasis or prominence, and no part

slighted, to make clear those ideas which are relatively more important. This can be done either by devoting extra space to the topics to be emphasized, or by putting them in the conspicuous positions of the composition—the beginning and the end. How is the material of this selection proportioned? What topic received fullest treatment? Determine if possible the reason. Are the introduction and conclusion of disproportionate length to the entire selection?

In this study of *The Importance of Dust* attention has been called to the main aspects of the rhetorical principles of Unity, Coherence, and Emphasis. All three of these principles are embraced in that fundamental principle with which this study began and which contains the whole secret of effective expression and communication,—the principle of organic unity.

Exercise 1. Every speaker or writer must always, as a condition of success, limit his subject to his space. The subjects given in the list below are obviously too comprehensive for a 300–500-word composition. Take the subject that interests you most, and select some phase of it about which you have knowledge enough for a composition of that length. State clearly and concisely in a single sentence the main point you will seek to develop. Then give an outline of the proposed treatment of your topic. The following will illustrate the manner of narrowing a broad subject to suitable size for a short composition: Broad Subject—*Education.* Slightly narrowed in scope—*College Education.* Still further narrowed until of suitable length for a 500-word composition—*The Object of a College Education.* Subject stated as a sentence—*The true object of a college education is not to give knowledge, but to give power.*

Friends	Science	Banks
Newspapers	Politics	Athletics
Novels	Chemistry	Large Cities
Books	Culture	American Universities
Aeroplanes	Architecture	Technical Education
Finance	Forestry	

Exercise 2. Follow the preparatory work done under Exercise 1 by writing out the whole composition.

Exercise 3. Write a composition of 400–600 words upon one of the following subjects, or some other approved by your instructor. Be sure to limit the subject so that it will be suitable for a short composition. Then, after carefully selecting the most suitable material, arrange and proportion it carefully. As a precaution against wasted

effort, make a preliminary outline and submit to your instructor for criticism. Then make a final outline according to his suggestions. Write the composition in full from this final outline.

The value of literary societies.
The evils (or benefits) of hazing.
The benefits of historical study (or any other study you may prefer writing about).
The advisability of a college track (or other) team.
The value of athletics as a part of college training.
The effect of fraternities upon college life.
The value (or the dangerous tendencies) of habit.
Student organizations as a means of training in leadership.
The influence of the newspaper.
Some of the uses of curiosity.
The habit of observing things.
The uses of rivers.
The desirability (or futility) of simplified spelling.
Evils of examinations.
Improvements in the game of football.

THE CHEMIST IN THE INDUSTRIES[1]

W. D. Richardson

As I see it, the chemist may be useful in the manufacturing industries in four different ways:

1. In the buying and selling of materials according to analysis.

2. In the chemical control of manufacturing operations by analyzing raw, intermediate and final products.

3. In a consulting capacity, interpreting chemical process, terms, and operations to the administrative heads of the business.

4. In the improvement of plant and processes, including the working up of by-products, cheapening of operations, and turning low-grade products into high-grade ones.

[1] A portion of an address delivered before the Indianapolis section of the American Chemical Society. Reprinted from *Science*, vol. 27, n. s. p. 805.

I shall take up these four different lines of work, one after another, somewhat in detail.

First—The buying and selling of materials according to analysis. I take it for granted that no modern manufacturing plant can run without power—power is indeed the chief distinguishing characteristic of modern plants as contrasted with ancient ones—and the principal source of power still is steam under pressure, and the heat necessary to generate steam is derived from burning coal. In very recent months plants have been constructed which derive their power from gas engines operating on producer gas, blast furnace gas, etc., and such plants may operate entirely without steam power. The demands made upon the world's coal supply for power have increased greatly in recent years; the coal supply cannot last forever; and so, means must be devised for making the coal supply last longer either by utilizing more of the energy or by working out methods for substituting other sources of energy for heat energy. The gas engine is the result of efforts in the first direction and the conversion of the gravitational energy of falling water into electrical energy is the result of the second. In spite of the efforts now being made to conserve the coal supply, the heat from burning coal applied to steam boilers is still the universal way of producing power. To operate a boiler plant a good water supply is necessary. There must not be too large a quantity of incrusting substances in the water, or scale will form in the boiler; the water must not be too alkaline, or it will prime or foam in the boiler. If only a poor water supply is to be had, then the chemist must provide a purification plant or boiler compound which will prevent or minimize the formation of scale. The coal received at all large plants is regularly analyzed and by many the coal is contracted for and bought on analysis. Thus for the very fundamental process of generating power for operating purposes, the manufacturing plant must call in the services of the chemist.

But every plant buys large quantities of supplies besides coal and water. For construction work there is Portland cement, which must be analyzed and tested; and lime and sand are fre-

quently examined by the chemist. The railroad buys its iron and steel, bronze and babbitt, brass and tin according to analysis; the packing-house buys its salt, sugar and vinegar in this way; the soap factory buys oils and tallows, caustic soda and soda ash, essential oils and artificial perfumes entirely according to composition and purity; the sulphuric-acid plant buys its pyrites; the fertilizer plant its potash salts; the glass factory its sand, its lime, its soda; the explosive factory its glycerine and nitric acid, all according to the chemist's certificate. The analytical chemist has come to be a factor of enormous importance in the affairs of the commercial world. The very standard of the basis of exchange is determined by his assay; he analyzes every product from stone and iron to food and spices.

Of course, the thought will occur to you: How was manufacture and exchange conducted at all in the days before chemistry and chemists became so important? How did manufacturers and business men get along at all? Well, they got along fairly well then, but to-day I am afraid their difficulties would be many. The keen competition of to-day and the more elaborate working-up of by-products, yes the greater complexity of modern society, have brought about the change. Still, even to-day there are plants of fair size which are operating without chemists. I know of a soap factory, for example, in which the fats are bought on inspection, the alkalies on the seller's analysis, and no control whatever is exercised over the chemical process of soap-making excepting that afforded by the sense of taste which is used in determining when the boiling soap is approximately neutral. The soap lyes are not refined, but are shipped in drums to the refiner.

Somebody may ask: How can a small plant afford to employ a chemist and so increase its pay-roll by a greater or less sum? My reply is that it is not necessary for the small plant to employ a chemist on the spot. At all the large commercial and industrial centres will be found commercial chemists who will make yearly contracts on the basis of the output, to handle all analyses and serve in a consulting capacity as well, in the

interest of the plant. I have in mind one such laboratory in Chicago, which serves in an analytical capacity for about four hundred small and large foundries at a moderate compensation for each one. Each day the foundries send in their samples and these are analyzed at night; in the morning the various foundries are notified by telegram or letter as to whether their mixtures are right or wrong, and if wrong they are told how to correct them.

The second way in which I have said the chemist is useful in the modern factory is in following what we call the chemical control work of the factory. In brief, this means the analysis of the raw material, of the intermediate products and of the final products of manufacture. In blast furnace practice, the control work would include the analysis of the ore, of the coke, and of the limestone which go to make up the charge, of the pig iron produced in the operation, and possibly of the slag for cement-making purposes and of the blast-furnace gases. This is an old story to chemists and to those who are familiar with the chemical profession, but I would like to emphasize the fact, that this technical analysis or control work is, so far as the operative side of an industry is concerned, the vital and important thing. There is no doubt that analysis is the backbone of chemistry, and it is well to remember that analytical methods cannot be made too exact. The business and commercial and manufacturing world to-day is scrutinizing intently the work of the analytical chemists, both in works and in commercial laboratories, and day by day is demanding more exact and carefully made analyses. I can see signs at the present time of demands in point of accuracy of analytical work which will tax to the utmost the resources of chemical invention. The question of accuracy and rapidity in technical analysis is a most important one and in the near future our great chemical society, through its division of industrial chemists and chemical engineers, must take up this question and by means of committees and coöperative work give the manufacturing world what it is demanding.

There is no factory engaged in the transformation of sub-

stances chemically which does not require this control work by chemists. In a soap factory, the raw fats and the alkalies are analyzed; during the process the product is examined for completeness of saponification; the lyes are analyzed for their glycerine content and for excess caustic soda and sodium carbonate; the crude glycerine must be analyzed and the chemically pure and dynamite glycerine after distillation. Finally the finished product must be analyzed from time to time, and the soap of other makers as well, for the sake of comparison.

The Portland cement industry has grown to enormous proportions in this country in recent years and in that industry, again, the turning out of strong and sound cement is a matter depending almost wholly upon the carefulness of the control exercised by the chemist. The limestone or marl and the clay or blast-furnace slag which go to make up the mix, must be analyzed with the greatest care, to insure a uniform product of high quality. I have mentioned the word "uniform." Probably no single thing in manufacture is more important than the turning out of a product which is of the same quality from day to day and from year to year. The public even to-day buys largely according to appearances, and, for example, if one lot of commercial fertilizer is gray and another brown, although of the same grade and composition, the farmer is very apt to have a strong prejudice in favor of one or the other.

The list of industries in which the chemical control work is vitally important might be extended indefinitely. I will only say that in every well-organized pottery works in the country, in every large brewery, in every oil works, gas works, wood distillation plant, varnish works, sugar factory, explosive plant, dye house, tannery, glue factory and fertilizer plant, not to mention those very modern lines of industry which are engaged in the manufacture of acids, alkalies and salts—the so-called heavy chemicals—there is a well-organized laboratory and chemical staff constantly engaged in this work of chemical control. It is hardly necessary, under these circumstances, to answer the question: Does it pay? if the question should be asked. I say unqualifiedly that not only does it pay, but it

nets the industry the largest return on the investment of any branch of the establishment. I will go further and say that during the next ten or twenty years, where there is one chemist working at a given industry now, there will be two or three chemists working then. And that this great increase in the chemical forces of this country will mean more to the development of the manufacturing industries here than mere words can express. Germany's preëminence in certain large lines of manufacture to-day is freely acknowledged to be due solely to the contributions which her scientific men, and chiefly her chemists, have made to the cause of manufacture.

The third way in which I stated that the chemist is useful in the manufacturing plant was in the capacity of consulting man, interpreting chemical processes, terms and operations to the administrative heads of the business. In a large plant there is constantly coming up a host of new problems and suggested processes, as well as incidental questions, which can only be properly handled by a technical chemist. To him comes the manager, the president, the superintendent or other members of the executive staff, asking for information: And on these occasions, the chemist is the man of ready reference for everybody. When the questions are coming in thick and fast, his information must be practically all that is recorded in existing and non-existing scientific books and journals and his mind must be as well organized as a card index in a library. There is no question concerning force or matter on this earth, the heavens above or the waters beneath, that the manager or superintendent cannot ask, or, I am happy to say, his chemist cannot answer with equal facility. What is the difference between salt and sugar? If an iron pipe will rust, why will not a lead pipe? Have you got a good recipe for taking aniline stains out of a tablecloth? What is the latest decision on the Board of Food and Drug Inspection? How much salt per day is the proper ration for draft horses? And the list might be carried on to infinity. All these questions, I say, the chemist can answer with as great facility as the layman can ask them.

The fourth sphere of usefulness which I suggested referred to

the improvement of plant and processes, including the working up of by-products and cheapening of operations, and turning low-grade products into high-grade ones. Work of this nature is to be viewed in a different light from the other kinds of work which I have described. I should say that while all plants require analytical and control work and also consulting work, there are many plants which can operate, and operate successfully, without any of the research work implied in the present category. This fact is not to be taken as a criticism against the plant, but is to be accepted as a natural feature of industrial operations. Not all plants can lead. There must always be a considerable number which work along the accepted lines of their particular branch with no great desire to take the initiative in developing plant and process. The man who can invent, describe, work out in detail, install and operate a new industrial process or an improvement on an old one, is an extremely rare person. He must have inventive ability, profound knowledge, keen insight, imagination, initiative, tireless energy and that wonderful faculty of elimination of the non-essential. One of the great mistakes of the present tendency in chemical education is, in my opinion, that every young student of chemistry is taught to believe, or at least is not taught to disbelieve, that on a modest or even a considerable foundation of chemical information he can become a research man in an industrial laboratory and an improver of processes in manufacture. This is a serious mistake. No amount of chemical training can change the nature or the talents of a man, and yet almost every young man who enters an industrial laboratory seems to have the idea that any work but research, or work of an executive nature, is not to be considered worthy. The simple result of this is that the men are failures as research or executive men if given an opportunity, and, further, because they do not regard as sufficiently important for their consideration that foundation of our science, analytical chemistry, they are bad analysts. It is an astonishing thing that the great rarity in an industrial laboratory is a first-class analyst. Most men, instead of looking upon skill in analysis as a desirable thing to attain, consider it as of secondary im-

portance. To them, apparently, the work of Berzelius, of Stas, of Fresenius and of Hillebrand does not appeal, or does not influence them greatly. I believe that every chemist, no matter what line he may be working along, whether a teacher in a high school, a university professor, a consulting chemist or a chemical engineer, should be first of all a capable analyst.

These remarks are somewhat aside from the immediate topic. The chemical engineer—for by this much-abused name I prefer to call those chemists who are able to improve plant and process—has a high calling. Fortunate indeed is the establishment which possesses such a man. In my own limited experience, not more than one chemist in one hundred (and possibly the ratio is lower yet) is entitled to be called by that name. And the greatest of these, the Bessemers, the Solvays, the LeBlancs, the Chances, the Lunges, the Knietsches, stand out as notable landmarks in the course of the history of chemistry.

QUESTIONS AND EXERCISES

The present selection supplements what has been said about the principles of organic structure in the exposition, and should be examined with reference to its structure and method. As it offers very little difficulty to the student, the making of a general plan and the analysis of its details of building up and joining together, may readily be made by adapting the questions in connection with Wallace's *The Importance of Dust*. The questions that follow call attention only to a few new matters.

1. Is the framework of the selection too evident? Will the fact that this selection was prepared for oral delivery, while Wallace's selection was prepared to be read, tend to cause a difference in the degree to which the landmarks of structure are displayed? Give reasons for your answer.

2. "It is doubtless unpleasant to have the hard framework of logical divisions showing too distinctly," says Leslie Stephen. " . . . But such aids to the memory may be removed too freely. The building may be injured by taking away the scaffolding." Discuss this statement.

Exercise 1. Write a composition of about 500 words on one of the following subjects. In treating the subject chosen, select three or four main headings, and arrange them in logical order. Clearly

state the subject and its divisions in the opening sentence, and then develop each division by means of particulars and details, illustrations, contrasts, etc. Be careful to make clear the transitions from one point to another.

The relation of a liberal education to life.
Causes of the decline of great nations.
Advantages of travel.
Dangers of success.
Some recent discoveries in science.
Ways in which my previous study of rhetoric has helped me.
The turning points in my life.
Why I chose the classical (or scientific) course.
What a tree needs for its growth.
Outlook for young men in physics (or some other science).
Opportunities for young men in engineering (or any other profession).
Franklin as a typical American.
Working one's way through college.
The arts of the Athenians.
Rome as a civilizer of her conquerors.
Causes of the French Revolution.
Essentials of a good shade tree.
Social life in agricultural communities.

Read: after writing theme.

THE SOCIAL VALUE OF THE COLLEGE-BRED[1]

WILLIAM JAMES

OF what use is a college training? We who have had it seldom hear the question raised—we might be a little nonplussed to answer it offhand. A certain amount of meditation has brought me to this as the pithiest reply which I myself can give: The best claim that a college education can possibly make on your respect, the best thing it can aspire to accomplish for you, is this: that it should *help you to know a good man when you see him.* This is as true of women's as of men's colleges;

[1] Reprinted from *McClure's Magazine*, vol. XXX, page 419, by permission.

but that it is neither a joke nor a one-sided abstraction I shall now endeavor to show.

What talk do we commonly hear about the contrast between college education and the education which business or technical or professional schools confer? The college education is called higher because it is supposed to be so general and so disinterested. At the "schools" you get a relatively narrow practical skill, you are told, whereas the "colleges" give you the more liberal culture, the broader outlook, the historical perspective, the philosophic atmosphere, or something which phrases of that sort try to express. You are made into an efficient instrument for doing a definite thing, you hear, at the schools; but, apart from that, you may remain a crude and smoky kind of petroleum, incapable of spreading light. The universities and colleges, on the other hand, although they may leave you less efficient for this or that practical task, suffuse your whole mentality with something more important than skill. They redeem you, make you well-bred; they make "good company" of you mentally. If they find you with a naturally boorish or caddish mind, they cannot leave you so, as a technical school may leave you. This, at least, is pretended; this is what we hear among college-trained people when they compare their education with every other sort. Now, exactly how much does this signify?

It is certain, to begin with, that the narrowest trade or professional training does something more for a man than to make a skilful practical tool of him—it makes him also a judge of other men's skill. Whether his trade be pleading at the bar or surgery or plastering or plumbing, it develops a critical sense in him for that sort of occupation. He understands the difference between second-rate and first-rate work in his whole branch of industry; he gets to know a good job in his own line as soon as he sees it; and getting to know this in his own line, he gets a faint sense of what good work may mean anyhow, that may, if circumstances favor, spread into his judgments elsewhere. Sound work, clean work, finished work; feeble work, slack work, sham work—these words express an identical contrast in many

different departments of activity. In so far forth, then, even the humblest manual trade may beget in one a certain small degree of power to judge of good work generally.

Now, what is supposed to be the line of us who have the higher college training? Is there any broader line—since our education claims primarily not to be "narrow"—in which we also are made good judges between what is first-rate and what is second-rate only? What is especially taught in the colleges has long been known by the name of the "humanities," and these are often identified with Greek and Latin. But it is only as literatures, not as languages, that Greek and Latin have any general humanity-value; so that in a broad sense the humanities mean literature primarily, and in a still broader sense the study of masterpieces in almost any field of human endeavor. Literature keeps the primacy; for it not only *consists* of masterpieces, but is largely *about* masterpieces, being little more than an appreciative chronicle of human master-strokes, so far as it takes the form of criticism and history. You can give humanistic value to almost anything by teaching it historically. Geology, economics, mechanics, are humanities when taught with reference to the successive achievements of the geniuses to which these sciences owe their being. Not taught thus, literature remains grammar, art a catalogue, history a list of dates, and natural science a sheet of formulas and weights and measures.

The sifting of human creations!—nothing less than this is what we ought to mean by the humanities. Essentially this means biography; what our colleges should teach is, therefore, biographical history, that not of politics merely, but of anything and everything so far as human efforts and conquests are factors that have played their part. Studying in this way, we learn what types of activity have stood the test of time; we acquire standards of the excellent and durable. All our arts and sciences and institutions are but so many quests of perfection on the part of men; and when we see how diverse the types of excellence may be, how various the tests, how flexible the adaptations, we gain a richer sense of what the terms "better" and "worse" may signify in general. Our critical sensibilities grow

both more acute and less fanatical. We sympathize with men's mistakes even in the act of penetrating them; we feel the pathos of lost causes and misguided epochs even while we applaud what overcame them.

Such words are vague and such ideas are inadequate, but their meaning is unmistakable. What the colleges—teaching humanities by examples which may be special, but which must be typical and pregnant—should at least try to give us, is a general sense of what, under various disgu ses, *superiority* has always signified and may still signify. The feeling for a good human job anywhere, the admiration of the really admirable, the disesteem of what is cheap and trashy and impermanent—this is what we call the critical sense, the sense for ideal values. It is the better part of what men know as wisdom. Some of us are wise in this way naturally and by genius; some of us never become so. But to have spent one's youth at college, in contact with the choice and rare and precious, and yet still to be a blind prig or vulgarian, unable to scent out human excellence or to divine it amid its accidents, to know it only when ticketed and labelled and forced on us by others, this indeed should be accounted the very calamity and shipwreck of a higher education.

The sense for human superiority ought, then, to be considered our line, as boring subways is the engineer's line and the surgeon's is appendicitis. Our colleges ought to have lit up in us a lasting relish for the better kind of man, a loss of appetite for mediocrities, and a disgust for cheapjacks. We ought to smell, as it were, the difference of quality in men and their proposals when we enter the world of affairs about us. Expertness in this might well atone for some of our awkwardness at accounts, for some of our ignorance of dynamos. The best claim we can make for the higher education, the best single phrase in which we can tell what it ought to do for us, is, then, exactly what I said: it should enable us to *know a good man when we see him.*

That the phrase is anything but an empty epigram follows from the fact that if you ask in what line it is most important

that a democracy like ours should have its sons and daughters skilful, you see that it is this line more than any other. "The people in their wisdom"—this is the kind of wisdom most needed by the people. Democracy is on its trial, and no one knows how it will stand the ordeal. Abounding about us are pessimistic prophets. Fickleness and violence used to be, but are no longer, the vices which they charge to democracy. What its critics now affirm is that its preferences are inveterately for the inferior. So it was in the beginning, they say, and so it will be world without end. Vulgarity enthroned and institutionalized, elbowing everything superior from the highway, this, they tell us, is our irremediable destiny; and the picture-papers of the European continent are already drawing Uncle Sam with the hog instead of the eagle for his heraldic emblem. The privileged aristocracies of the foretime, with all their iniquities, did at least preserve some taste for higher human quality and honor certain forms of refinement by their enduring traditions. But when democracy is sovereign, its doubters say, nobility will form a sort of invisible church, and sincerity and refinement, stripped of honor, precedence, and favor, will have to vegetate on sufferance in private corners. They will have no general influence. They will be harmless eccentricities.

Now, who can be absolutely certain that this may not be the career of democracy? Nothing future is quite secure; states enough have inwardly rotted; and democracy as a whole may undergo self-poisoning. But, on the other hand, democracy is a kind of religion, and we are bound not to admit its failure. Faiths and utopias are the noblest exercise of human reason, and no one with a spark of reason in him will sit down fatalistically before the croaker's picture. The best of us are filled with the contrary vision of a democracy stumbling through every error till its institutions glow with justice and its customs shine with beauty. Our better men *shall* show the way and we *shall* follow them; so we are brought round again to the mission of the higher education in helping us to know the better kind of man whenever we see him.

The notion that a people can run itself and its affairs anonymously is now well known to be the silliest of absurdities. Mankind does nothing save through initiatives on the part of inventors, great or small, and imitation by the rest of us—these are the sole factors active in human progress. Individuals of genius show the way, and set the patterns, which common people then adopt and follow. *The rivalry of the patterns is the history of the world.* Our democratic problem thus is statable in ultra-simple terms: Who are the kind of men from whom our majorities shall take their cue? Whom shall they treat as rightful leaders? We and our leaders are the x and the y of the equation here; all other historic circumstances, be they economical, political, or intellectual, are only the background of occasion on which the living drama works itself out between us.

In this very simple way does the value of our educated class define itself: we more than others should be able to divine the worthier and better leaders. The terms here are monstrously simplified, of course, but such a bird's-eye view lets us immediately take our bearings. In our democracy, where everything else is so shifting, we alumni and alumnæ of the colleges are the only permanent presence that corresponds to the aristocracy in older countries. We have continuous traditions, as they have; our motto, too, is *noblesse oblige;* and, unlike them, we stand for ideal interests solely, for we have no corporate selfishness and wield no powers of corruption. We ought to have our own class-consciousness. "Les intellectuels"! What prouder club-name could there be than this one, used ironically by the party of "red blood," the party of every stupid prejudice and passion, during the anti-Dreyfus craze, to satirize the men in France who still retained some critical sense and judgment! Critical sense, it has to be confessed, is not an exciting term, hardly a banner to carry in processions. Affections for old habit, currents of self-interest, and gales of passion are the forces that keep the human ship moving; and the pressure of the judicious pilot's hand upon the tiller is a relatively insignificant energy. But the affections, passions, and interests are shifting, successive,

and distraught; they blow in alternation while the pilot's hand is steadfast. He knows the compass, and, with all the leeways he is obliged to tack toward, he always makes some headway. A small force, if it never lets up, will accumulate effects more considerable than those of much greater forces if these work inconsistently. The ceaseless whisper of the more permanent ideals, the steady tug of truth and justice, give them but time, *must* warp the world in their direction.

This bird's-eye view of the general steering function of the college-bred amid the driftings of democracy ought to help us to a wider vision of what our colleges themselves should aim at. If we are to be the yeast-cake for democracy's dough, if we are to make it rise with culture's preferences, we must see to it that culture spreads broad sails. We must shake the old double reefs out of the canvas into the wind and sunshine, and let in every modern subject, sure that any subject will prove humanistic, if its setting be kept only wide enough.

Stevenson says somewhere to his reader: "You think you are just making this bargain, but you are really laying down a link in the policy of mankind." Well, your technical school should enable you to make your bargain splendidly; but your college should show you just the place of that kind of bargain —a pretty poor place, possibly—in the whole policy of mankind. That is the kind of liberal outlook, of perspective, of atmosphere, which should surround every subject as a college deals with it.

We of the colleges must eradicate a curious notion which numbers of good people have about such ancient seats of learning as Harvard. To many ignorant outsiders, that name suggests little more than a kind of sterilized conceit and incapacity for being pleased. In Edith Wyatt's exquisite book of Chicago sketches called "Every One his Own Way," there is a couple who stand for culture in the sense of exclusiveness, Richard Elliot and his feminine counterpart—feeble caricatures of mankind, unable to know any good thing when they see it, incapable of enjoyment unless a printed label gives them leave. Possibly this type of culture may exist near Cambridge and Boston, there may be specimens there, for priggishness is just like

painter's colic or any other trade-disease. But every good college makes its students immune against this malady, of which the microbe haunts the neighborhood-printed pages. It does so by its general tone being too hearty for the microbe's life. Real culture lives by sympathies and admirations, not by dislikes and disdains—under all misleading wrappings it pounces unerringly upon the human core. If a college, through the inferior human influences that have grown regnant there, fails to catch the robuster tone, its failure is colossal, for its social function stops: democracy gives it a wide berth, turns toward it a deaf ear.

"Tone," to be sure, is a terribly vague word to use, but there is no other, and this whole meditation is over questions of tone. By their tone are all things human either lost or saved. If democracy is to be saved it must catch the higher, healthier tone. If we are to impress it with our preferences, we ourselves must use the proper tone, which we, in turn, must have caught from our own teachers. It all reverts in the end to the action of innumerable imitative individua s upon each other and to the question of whose tone has the highest spreading power. As a class, we college graduates should look to it that *ours* has spreading power. It ought to have the highest spreading power.

In our essential function of indicating the better men, we now have formidable competitors outside. McClure's Magazine, the American Magazine, Collier's Weekly and, in its fashion, the World's Work, constitute together a real popular university along this very line. It would be a pity if any future historian were to have to write words like these: "By the middle of the twentieth century the higher institutions of learning had lost all influence over public opinion in the United States. But the mission of raising the tone of democracy, which they had proved themselves so lamentably unfitted to exert, was assumed with rare enthusiasm and prosecuted with extraordinary skill and success by a new educational power; and for the clarification of their human sympathies and elevation of their human preferences, the people at large acquired the habit of resorting

exclusively to the guidance of certain private literary adventures, commonly designated in the market by the affectionate name of ten-cent magazines."

Must not we of the colleges see to it that no historian shall ever say anything like this? Vague as the phrase of knowing a good man when you see him may be, diffuse and indefinite as one must leave its application, is there any other formula that describes so well the result at which our institutions *ought* to aim? If they do that, they do the best thing conceivable. If they fail to do it, they fail in very deed. It surely is a fine synthetic formula. If our faculties and graduates could once collectively come to realize it as the great underlying purpose toward which they have always been more or less obscurely groping, a great clearness would be shed over many of their problems; and, as for their influence in the midst of our social system, it would embark upon a new career of strength.

QUESTIONS AND EXERCISES

Like the two preceding selections, this article by James should be studied from the point of view of structure. The questions given in connection with Wallace's *The Importance of Dust* may be followed.

Exercises.—(See pp. 14 and 22).

ADAPTATION TO THE READER

THE METHOD OF SCIENTIFIC INVESTIGATION[1]

THOMAS HENRY HUXLEY

THE method of scientific investigation is nothing but the expression of the necessary mode of working of the human mind. It is simply the mode at which all phenomena are reasoned about, rendered precise and exact. There is no more difference, but there is just the same kind of difference, between the mental operations of a man of science and those of an ordinary person, as there is between the operations and methods of a baker or of a butcher weighing out his goods in common scales, and the operations of a chemist in performing a difficult and complex analysis by means of his balance and finely graduated scales. It is not that the action of the scales in the one case, and the balance in the other, differ in the principles of their construction or manner of working; but the beam of one is set on an infinitely finer axis than the other, and of course turns by the addition of a much smaller weight.

You will understand this better, perhaps, if I give you some familiar example. You have all heard it repeated, I dare say, that men of science work by means of induction and deduction, and that by the help of these operations, they, in a sort of sense, wring from Nature certain other things, which are called natural laws, and causes, and that out of these, by some cunning skill of their own, they build up hypotheses and theories. And it is imagined by many, that the operations of the common mind can be by no means compared with these processes, and

[1] Reprinted from *Darwiniana*, by permission of Messrs. D. Appleton & Co.

that they have to be acquired by a sort of special apprenticeship to the craft. To hear all these large words, you would think that the mind of a man of science must be constituted differently from that of his fellow men; but if you will not be frightened by terms, you will discover that you are quite wrong, and that all these terrible apparatus are being used by yourselves every day and every hour of your lives.

There is a well-known incident in one of Molière's plays, where the author makes the hero express unbounded delight on being told that he had been talking prose during the whole of his life. In the same way, I trust, that you will take comfort, and be delighted with yourselves, on the discovery that you have been acting on the principles of inductive and deductive philosophy during the same period. Probably there is not one here who has not in the course of the day had occasion to set in motion a complex train of reasoning, of the very same kind, though differing of course in degree, as that which a scientific man goes through in tracing the causes of natural phenomena.

A very trivial circumstance will serve to exemplify this. Suppose you go into a fruiterer's shop, wanting an apple,—you take up one, and, on biting it, you find it is sour; you look at it, and see that it is hard and green. You take up another one, and that too is hard, green, and sour. The shopman offers you a third; but, before biting it, you examine it, and find that it is hard and green, and you immediately say that you will not have it, as it must be sour, like those that you have already tried.

Nothing can be more simple than that, you think; but if you will take the trouble to analyze and trace out into its logical elements what has been done by the mind, you will be greatly surprised. In the first place, you have performed the operation of induction. You found that, in two experiences, hardness and greenness in apples went together with sourness. It was so in the first case, and it was confirmed by the second. True, it is a very small basis, but still it is enough to make an induction from; you generalize the facts, and you expect to find sourness in apples where you get hardness and greenness.

You found upon that a general law, that all hard and green apples are sour; and that, so far as it goes, is a perfect induction. Well, having got your natural law in this way, when you are offered another apple which you find is hard and green, you say, "All hard and green apples are sour; this apple is hard and green, therefore this apple is sour." That train of reasoning is what logicians call a syllogism, and has all its various parts and terms,—its major premiss, its minor premiss, and its conclusion, and, by the help of further reasoning, which, if drawn out, would have to be exhibited in two or three other syllogisms, you arrive at your final determination, "I will not have that apple." So that, you see, you have, in the first place, established a law by induction, and upon that you have founded a deduction, and reasoned out the special conclusion of the particular case. Well now, suppose, having got your law, that at some time afterwards, you are discussing the qualities of apples with a friend: you will say to him, "It is a very curious thing,—but I find that all hard and green apples are sour!" Your friend says to you, "But how do you know that?" You at once reply, "Oh, because I have tried them over and over again, and have always found them to be so." Well, if we were talking science instead of common sense, we should call that an experimental verification. And, if still opposed, you go further, and say, "I have heard from the people in Somersetshire and Devonshire, where a large number of apples are grown, that they have observed the same thing. It is also found to be the case in Normandy, and in North America. In short, I find it to be the universal experience of mankind wherever attention has been directed to the subject." Whereupon, your friend, unless he is a very unreasonable man, agrees with you, and is convinced that you are quite right in the conclusion you have drawn. He believes, although perhaps he does not know he believes it, that the more extensive verifications are,—that the more frequently experiments have been made, and results of the same kind arrived at,—that the more varied the conditions under which the same results are obtained the more certain is the ultimate conclusion, and he disputes the question

no further. He sees that the experiment has been tried under all sorts of conditions, as to time, place, and people, with the same result; and he says with you, therefore, that the law you have laid down must be a good one, and he must believe it.

In science we do the same thing;—the philosopher exercises precisely the same faculties, though in a much more delicate manner. In scientific inquiry it becomes a matter of duty to expose a supposed law to every possible kind of verification, and to take care, moreover, that this is done intentionally, and not left to a mere accident, as in the case of the apples. And in science, as in common life, our confidence in a law is in exact proportion to the absence of variation in the result of our experimental verifications. For instance, if you let go your grasp of an article you may have in your hand, it will immediately fall to the ground. That is a very common verification of one of the best established laws of nature—that of gravitation. The method by which men of science establish the existence of that law is exactly the same as that by which we have established the trivial proposition about the sourness of hard and green apples. But we believe it in such an extensive, thorough, and unhesitating manner because the universal experience of mankind verifies it, and we can verify it ourselves at any time; and that is the strongest possible foundation on which any natural law can rest.

So much, then, by way of proof that the method of establishing laws in science is exactly the same as that pursued in common life. Let us now turn to another matter (though really it is but another phase of the same question), and that is, the method by which, from the relations of certain phenomena, we prove that some stand in the position of causes towards the others.

I want to put the case clearly before you, and will therefore show you what I mean by another familiar example. I will suppose that one of you, on coming down in the morning to the parlor of your house, finds that a tea-pot and some spoons which had been left in the room on the previous evening are gone,—the window is open, and you observe the mark of a

dirty hand on the window-frame, and perhaps, in addition to that, you notice the impress of a hob-nailed shoe on the gravel outside. All these phenomena have struck your attention instantly, and before two seconds have passed you say, "Oh, somebody has broken open the window, entered the room, and run off with the spoons and the tea-pot!" That speech is out of your mouth in a moment. And you will probably add, "I know there has; I am quite sure of it!" You mean to say exactly what you know; but in reality you are giving expression to what is, in all essential particulars, an hypothesis. You do not *know* it at all; it is nothing but an hypothesis rapidly framed in your own mind. And it is an hypothesis founded on a long train of inductions and deductions.

What are those inductions and deductions, and how have you got at this hypothesis? You have observed, in the first place, that the window is open; but by a train of reasoning involving many inductions and deductions, you have probably arrived long before at the general law—and a very good one it is—that windows do not open of themselves; and you therefore conclude that something has opened the window. A second general law that you have arrived at in the same way is, that tea-pots and spoons do not go out of a window spontaneously, and you are satisfied that, as they are not now where you left them, they have been removed. In the third place, you look at the marks on the window-sill, and the shoe-marks outside, and you say that in all previous experience the former kind of mark has never been produced by anything else but the hand of a human being; and the same experience shows that no other animal but man at present wears shoes with hob-nails in them such as would produce the marks in the gravel. I do not know, even if we could discover any of those "missing links" that are talked about, that they would help us to any other conclusion! At any rate the law which states our present experience is strong enough for my present purpose. You next reach the conclusion that, as these kind of marks have not been left by any other animal than men, or are liable to be formed in any other way than a man's hand and shoe, the marks in question have been

formed by a man in that way. You have, further, a general law, founded on observation and experience, and that, too, is, I am sorry to say, a very universal and unimpeachable one,—that some men are thieves; and you assume at once from all these premisses—and that is what constitutes your hypothesis—that the man who made the marks outside and on the window-sill, opened the window, got into the room, and stole your tea-pot and spoons. You have now arrived at a *vera causa;*—you have assumed a cause which, it is plain, is competent to produce all the phenomena you have observed. You can explain all these phenomena only by the hypothesis of a thief. But that is a hypothetical conclusion, of the justice of which you have no absolute proof at all; it is only rendered highly probable by a series of inductive and deductive reasonings.

I suppose your first action, assuming that you are a man of ordinary common sense, and that you have established this hypothesis to your own satisfaction, will very likely be to go off for the police, and set them on the track of the burglar, with the view to the recovery of your property. But just as you are starting with this object, some person comes in, and on learning what you are about, says, "My good friend, you are going on a great deal too fast. How do you know that the man who really made the marks took the spoons? It might have been a monkey that took them, and the man may have merely looked in afterwards." You would probably reply, "Well, that is all very well, but you see it is contrary to all experience of the way tea-pots and spoons are abstracted; so that, at any rate, your hypothesis is less probable than mine." While you are talking the thing over in this way, another friend arrives, one of the good kind of people that I was talking of a little while ago. And he might say, "Oh, my dear sir, you are certainly going on a great deal too fast. You are most presumptuous. You admit that all these occurrences took place when you were fast asleep, at a time when you could not possibly have known anything about what was taking place. How do you know that the laws of Nature are not suspended during the night? It may be that there has been some kind of supernatural inter-

ference in this case." In point of fact, he declares that your hypothesis is one of which you cannot at all demonstrate the truth, and that you are by no means sure that the laws of Nature are the same when you are asleep as when you are awake.

Well, now, you cannot at the moment answer that kind of reasoning. You feel that your worthy friend has you somewhat at a disadvantage. You will feel perfectly convinced in your own mind, however, that you are quite right, and you say to him, "My good friend, I can only be guided by the natural probabilities of the case, and if you will be kind enough to stand aside and permit me to pass, I will go and fetch the police." Well, we will suppose that your journey is successful, and that by good luck you meet with a policeman; that eventually the burglar is found with your property on his person, and the marks correspond to his hand and to his boots. Probably any jury would consider those facts a very good experimental verification of your hypothesis, touching the cause of the abnormal phenomena observed in your parlor, and would act accordingly.

Now, in this supposititious case, I have taken phenomena of a very common kind, in order that you might see what are the different steps in an ordinary process of reasoning, if you will only take the trouble to analyze it carefully. All the operations I have described, you will see, are involved in the mind of any man of sense in leading him to a conclusion as to the course he should take in order to make good a robbery and punish the offender. I say that you are led, in that case, to your conclusion by exactly the same train of reasoning as that which a man of science pursues when he is endeavoring to discover the origin and laws of the most occult phenomena. The process is, and always must be, the same; and precisely the same mode of reasoning was employed by Newton and Laplace in their endeavors to discover and define the causes of the movements of the heavenly bodies, as you, with your own common sense, would employ to detect a burglar. The only difference is, that the nature of the inquiry being more abstruse,

every step has to be most carefully watched, so that there may not be a single crack or flaw in your hypothesis. A flaw or crack in many of the hypotheses of daily life may be of little or no moment as affecting the general correctness of the conclusions at which we may arrive; but, in a scientific inquiry, a fallacy, great or small, is always of importance, and is sure to be in the long run constantly productive of mischievous, if not fatal results.

Do not allow yourselves to be misled by the common notion that an hypothesis is untrustworthy simply because it is an hypothesis. It is often urged, in respect to some scientific conclusion, that, after all, it is only an hypothesis. But what more have we to guide us in nine-tenths of the most important affairs of daily life than hypotheses, and often very ill-based ones? So that in science, where the evidence of an hypothesis is subjected to the most rigid examination, we may rightly pursue the same course. You may have hypotheses and hypotheses. A man may say, if he likes, that the moon is made of green cheese: that is an hypothesis. But another man, who has devoted a great deal of time and attention to the subject, and availed himself of the most powerful telescopes and the results of the observations of others, declares that in his opinion it is probably composed of materials very similar to those of which our own earth is made up: and that is also only an hypothesis. But I need not tell you that there is an enormous difference in the value of the two hypotheses. That one which is based on sound scientific knowledge is sure to have a corresponding value; and that which is a mere hasty random guess is likely to have but little value. Every great step in our progress in discovering causes has been made in exactly the same way as that which I have detailed to you. A person observing the occurrence of certain facts and phenomena asks, naturally enough, what process, what kind of operation known to occur in Nature, applied to the particular case, will unravel and explain the mystery? Hence you have the scientific hypothesis; and its value will be proportionate to the care and completeness with which its basis had been tested and verified.

It is in these matters as in the commonest affairs of practical life: the guess of the fool will be folly, while the guess of the wise man will contain wisdom. In all cases, you see that the value of the result depends on the patience and faithfulness with which the investigator applies to his hypothesis every possible kind of verification.

QUESTIONS AND EXERCISES

Having studied in the preceding selections the principle of organic unity in connection with the composition as a whole, we pass on in the present selection to another very important principle. It was referred to incidentally in the quotation from Ruskin on page 11. According to Ruskin, not only must the ideas of a composition be carefully adjusted to each other and the whole, but they must also be presented "so that the entire chain of thoughts offered to the beholder's mind shall be received by him with as much delight and with as little effort as possible." The first was the principle of organization; the second is the principle of adaptation. It requires such adjustment or adaptation of the composition to the reader's capacities that he will understand clearly and be interested. The writer must keep constantly before his imagination the reader,—his probable state of mind, mental capacity, habits of thought, tastes, aptitudes, etc.

Huxley's popular lectures on scientific topics are models in the careful adaptation of thought and expression to a particular audience,—in the case of the present selection, workingmen. His success may be attributed to his carefulness regarding the principle of adaptation in its two aspects of (1) adaptation in the broad architectural plan of the work, and (2) adaptation in form and manner of expression. The method of this selection is very simple: Huxley, in the opening sentence, lays down the principle he proposes to elucidate; next he elaborates first one and then another illustration of it.

1. Note the excellent unity of the piece. Condense each paragraph into a short sentence or clause, writing these consecutively so that they shall constitute a broad outline of the selection. Is the arrangement clear and logical? Why could not an *hypothesis* have been explained before *inductive reasoning*. Has Huxley apparently tried to put first what the audience knows already or could grasp most easily? Does he seem to be following the order of difficulty,—leading from the known to the unknown, from the easier to the

harder? Does his purpose and audience seem to have dictated this arrangement of the parts of the lecture? Notice how clearly the divisions of the discussion are marked.

2. Although Huxley shows himself skilful in adapting his lecture to his audience so far as arrangement of material is concerned, he perhaps shows greater skill in meeting the requirements of adaptation in manner and phrasing. Note how painstaking Huxley is to reënforce his broad, abstract statements by concrete illustrations. Are these generally drawn from ordinary, easily understood things? Consider the appropriateness of these particular examples for the audience addressed. Do these concrete illustrations accomplish anything more than the making clear of certain difficult ideas? Find Huxley's own statement in this selection concerning the usefulness of these "familiar examples," as he terms them.

3. In the light of the object and the occasion of this lecture, what kind of words would you think it proper for Huxley to use? Are any of the words unintelligible to you? Is the language at all technical? When it is necessary to use an unfamiliar term, what precaution does Huxley take to insure its comprehension? What does the lecture gain from the direct discourse which occurs frequently? What from the conversational expletives and the use of the second person? What in general would be the value to the scientist himself of the task of putting the truths learned in the field, the laboratory, and the museum into language generally intelligible?

For lectures before workingmen, Huxley made as careful preparation as for his more conspicuous discourses before scientific bodies. The care with which he worked is shown by the following quotations from his letters. In one place he writes: "It constantly becomes more and more difficult for me to finish things satisfactorily." In another letter he says: "The fact is that I have a great love and a great respect for my native tongue and take great pains to use it properly. Sometimes I write essays half a dozen times before I can get them into proper shape, and I believe I become more fastidious as I grow older." The result of Huxley's "great pains" was the attainment of what some one describes as "that mastery of clear expression for which he labored, the saying exactly what he meant, neither too much nor too little, without confusion and without obscurity." No one familiar with Huxley's writings will doubt the truth of what Professor Lankester said of them: "For my own part, I know of no writing which by its mere form even apart from the supreme interest of the matter with which it mostly deals gives me

so much pleasure as that of the author of these lectures. . . . Everything which entered the author's brain by eyes or ears, whether of recondite philosophy, biological fact, or political programme, comes out again to us,—classified, sifted, arranged, and vivified by its passage through the logical machine of his strong individuality."

Exercise 1. Write two accounts of some machine or experiment, one for a younger brother, the other for a fellow-member of the class. Give particular attention in both accounts to the problem of adaptation to the reader.

Exercise 2. Explain clearly, after the manner of Huxley, with effective arrangement and suitable analogies and illustrations, some scientific principle familiar to you. Address the explanation to a laboring man who has had but little education.

Exercise 3. Explain in suitable language for a person younger than yourself one of the following topics:

Hypnotism.
The solar spectrum.
A technical education.
The right of eminent domain.
The comparative method in literature.

Exercise 4. Write an essay on the value of foreign missions. Address it to a church member with the intention of inducing him to make a contribution. Write another essay on the same subject for a business man who has never given foreign missions any consideration. Compare the two essays and note differences in selection and arrangement of material due to your attempt to adapt them to the two readers.

THE WEB-FOOT ENGINEER [1]

BENJAMIN BROOKS

WHILE the "tallest building in the world"—which is always being built somewhere in New York—continues to absorb popular wonder and attention, and the great cantilevers and suspension-bridges continue to bear up under their weight of criticism without visible means of support, the most important

[1] Reprinted by permission from *McClure's Magazine*, Vol. XXXIII, page 73.

but least spectacular individual concerned in their existence continues his unobtrusive subterranean operations almost unknown, except as he may from time to time annoy us with the blocking of a thoroughfare or the creation of a local earthquake. Thus the term "skyscraper" is an old one, while the term "earthscraper" was invented but yesterday. I have spoken of this retiring person as web-footed because, as with ducks and cranes and other animals thus endowed by nature, the business of his life is in the mud, the shifty quicksand, and under water; and whatever he may lack in the spectacular or picturesque, he is nevertheless most worthy of notice for his unequalled ingenuity.

The web-foot engineer has three main problems to deal with: to support a tremendous weight over soft mud or quicksand; to open and maintain a clear passage through it; to drain it off and eliminate it altogether. Out of these three main problems grow an endless combination of difficulties that he must devise means of overcoming; but in all of them enters his arch-enemy, water —water, the basis of all big engineering, locater of railways and thoroughfares, distributor of population, maker of treaties, destroyer of man's half-baked, faint-hearted attempts, but conserver of his truly great works.

There is an old, shop-worn fallacy that the great man is always at hand awaiting the occasion that will bring him out of oblivion and put him on his mettle; but the two greatest cities in the world both waited years in an overcrowded, river-girt condition, loudly proclaiming the occasion for a great man; yet it was a long time before he came to liberate them. He appeared only in the last century to the city of London after that town had overflowed its bridges for generations, and he presented a scheme for driving a tunnel under the Thames through the comparatively soft clay. Everybody knew that so large a hole as a tunnel could not be dug and kept open under the Thames; but if a short, portable piece of completed tunnel could be continuously pushed ahead and added to from behind, what then? He conceived a steel contrivance just a trifle bigger around than the tunnel was to be, shaped in about the

proportions of a baking-powder can, with no bottom and no top, but having a diaphragm or partition across the middle of it. When this had been sunk down and started on the line of the tunnel, the forward part of the shell would hold up the overhanging mud sufficiently so that men could work through little doorways in the partition, digging the earth from in front and loading it into cars to be carried out behind; and at the same time, on the interior of the after portion, other men could bolt together the steel or iron sections of the tunnel lining.

A short section having been completed in this manner, the whole machine could push itself ahead with a kick—that is, with powerful hydraulic jacks pressing against the completed part of the tunnel. Imagine having forced a large, empty sugar barrel horizontally into a bank of earth, first having knocked out both heads. By crawling into the barrel a man could, with considerable discomfort and perspiration, dig away the earth some little distance in advance of the barrel, and, given something to kick against, he could push himself and his barrel farther into the cavity he had dug. Now, if another man were to hand him the necessary staves and *internal* hoops, he could build a second and slightly smaller barrel partly inside of the first one. He might then do more digging and more pushing ahead, until he had proceeded far enough to build a second small barrel and fit it tightly to the end of the first small barrel. In this way, since a small barrel always lapped partly inside of the big one in which he worked, the earth could never cave in and cut him off from daylight; and so long as he was provided with staves, hoops, food, water, and air, he could burrow on indefinitely.

Such, in a nutshell, was the idea of a certain web-foot engineer, Sir Marc Brunel, in 1824—the simplest, best, most ingenious idea that has occurred to engineers in many years. The great cities had waited for it so long that they accepted it ravenously. Tunnels burrowed under the Thames, the Seine, the Hudson. Poor old tunnels that had set out without it and gone bankrupt at the discouraging rate of a few inches a week, took on a new lease of life and set out again at many feet a day; and they are

going yet—all day and all night, steadily, blindly, but surely, on under the rivers to set the cities free.

Of course the original idea has to be modified somewhat for every particular tunnel and for each variety of mud. If the mud is full of gravel and boulders, the forward half of the machine has to be worked under compressed air to balance the pressure of earth and water; and the workers have to be provided with safety locks in case of a sudden inrush of water. If you invert a glass in a bowl of water and press it down, the water will not rise to any extent in the glass. On this principle, little inverted steel pockets are made for the men to retreat into in case of accident and keep their heads above water until assistance can come.

If, on the other hand, the earth is tough and regular instead of being dug out by miners the way is cut automatically with a large rotary cutter. If it is softer still and too mushy to be counterbalanced by compressed air, then the top of the forward shield is made very long, so as to let the mud cave in on a long slant and still not fall from above. When it gets to the consistency of porridge, as it is at the bottom of the Hudson, it is found possible to force the shield ahead without any digging, merely letting the mud ooze through the partition doors and shovelling it into the cars. At times it was thought possible to force ahead without opening the doors at all—merely pushing the mud out of the way; but this was too simple to be strictly according to the rules of the game, and the obstacle presented itself that the extra weight of this overcrowded mud was enough to lift or float the whole tunnel up out of its proper alignment.

Again, in the Boston tunnel, the mud was so accommodating as to stand up almost without support, so that the whole machine was reduced to a simple steel arch on rollers without any partition at all.

Another of the web-foot engineer's problems—to support a great weight on or over mud—would seem to be simpler than the under-water tunnel problem; and, up to a certain limit, it is. If the soil is capable of holding only one ton on each square foot, and a certain column is to sustain five hundred tons, all one

has to do is to spread out its base by criss-crossed steel beams and concrete slabs to the extent of five hundred square feet—if one has the room; and if the adjoining columns are close enough to it so that their bases touch, you have your structure floating on one continuous slab. Nothing could be simpler or easier—unless some other man with an equally heavy structure to support comes to excavate a foundation alongside of yours, and the mud runs out from under you. I was once talking with a well-borer in Boston who put down wells, elevator-rams, test holes for engineers, and so on. He probably knew more about the underground condition of his town than any other citizen. "If," said he, "I were ever called on to lay siege to Boston, it would not be with guns, fire, or dynamite. I should simply sink a pit down near the Post-Office, where John Winthrop's spring still shows up, install a big pump, and begin sucking out the quicksand. In about two days every large building in town would be a wreck." And so it undoubtedly would be.

This brings us to the ancient expedient of pile-driving. Many thousands of years ago the more ingenious and weaker part of the population of central Europe maintained itself against the more warlike and less mechanically skilful part by building itself pile villages out over the lakes. And the stumps of the piles on which Cæsar crossed over the Rhine are still to be found, in proof that his luminous Commentaries are not fiction; yet, even in this late day, the science is still young, and every few months bring forth an improvement in the making and driving of piles. In fact, so perverse and unexpected is the behavior of piling that I doubt if it can ever be reduced to a science. For instance, you may drive a ninety-foot pile into soft river mud so easily that it will fall of its own weight to a penetration of twenty or thirty feet, and go indefinitely two or three feet to the blow of a fairly heavy hammer; and, having driven it, you may immediately hook a line to it and pull it out again. But allow it to remain driven for an hour or so, and you may sink a forty-ton barge and break every line in your outfit trying to budge it. Similarly you may pound for an hour on the unfortunate head of a pile that penetrates quick-

sand. A horse or a man could not stand for a minute on the spot without sinking out of sight; yet the pile, as if being driven on a rubber buffer, will bounce stubbornly under every blow, but sink scarcely a hair's breadth. Moreover, having, in the course of a long and discouraging day, succeeded in getting two or three bents down to a minimum depth, you may return next morning to see your whole day's work floated up and out during the night and idly sunning itself on a sand-bar a few miles downstream. Yet if you were wise enough to run a long pipe down by the pile as it was being driven, and keep a stream of water forced down through it to bore away the sand, you would find, immediately on withdrawing the pipe and stopping the water, that the pile was stuck fast, there to remain forever. Nobody knows how much a pile of given length and girth will bear till he tries it; but the holding power as compared with any spread-out surface footing is enormous.

It unfortunately happens, however, that although a sound stick of timber will remain such in thoroughly wet earth for ten thousand years, it cannot be trusted to last ten years in dry soil. Furthermore, if it stand in salt sea water, that harmless-looking but very costly long white worm, the teredo,—which, although neither ugly nor venomous, wears a boring-mill on its head,—will certainly make short work of it. Ten months in temperate water is all he needs to make honeycomb of the best stick of pine that ever grew.

To prevent this destruction and decay, then, it is obviously necessary to stop all timber work underground, below the possibility of dryness; and this is what takes most foundation work out of the hands of the top-soil contractor and places it in the hands of the web-foot. There is always some place in New York, and most other large cities in America, where he is to be seen making day and night and the neighboring property hideous with his smoking, pounding drivers and creaking derricks. First you see him taking great pains to build himself a water-tight dam of driven planks (he refers to them as sheet piling) or steel staves. Then come his bulky timbers as thick as a man's body, blocking the streets temporarily; and after

these are placed, his ravenous bucket begins to bite out the dirt from the inclosure. Then his driver pounds down the piles that are to do the supporting of the piers, forcing them below the water, and driving them still farther with another short pile mounted temporarily upon their vanished heads. After this he has the choice of pumping out the water and sawing them off evenly, or of rigging a buzz-saw on a long vertical, revolving shaft to cut them off under water. He has a like choice in placing his pier upon their heads. With the water pumped away, he may make a dry-land job of it; or, leaving the water standing, he may lower the concrete in specially constructed buckets that remain tight until they touch bottom and then accommodatingly dump their cargoes without allowing them to be washed away; or he may drop all the concrete down through a steel or canvas pipe moved about over the pile-heads, or deposit it sewed up in bags. New Yorkers who habitually passed the site will remember seeing these piling and capping operations going on to make foundations for the then heaviest and tallest Park Row Building.

All these processes are delightfully simple to write down, but gray hairs and insomnia lurk in their actual doing. I once developed slight symptoms of this sort over a project—the building of a line of piers through a marshland where a railway crossed a slough that promised some day to be dredged out and made navigable water. On account of the modest shell-headed worm, piles had to be cut off thirty-five feet below tide—which meant about the same distance below ground. Everything went beautifully. The sheet piling went in like a gimlet into cheese, the big buckets ate up a yard of mud a minute, and the discharge water from the pumps sluiced it out to sea. Everybody was happy. But when the excavation was forty feet deep and the pile-driving began at that level, all happiness ceased. The very first pile that went down penetrated a limitless reservoir of quicksand. In an hour the pile had become the centre of a funnel-shaped crater another forty feet deep below the pit, from which spouted up tons of sand and water; and, in spite of all the pumping that could be done, the big excavation that had

taken so many weeks to dig was full again. Moreover, having been undermined to the extent of what flowed into the excavation, the entire surrounding territory for a radius of a thousand feet began to sink. Down went the trestle and the track; down went the big derrick and rolled over on its side, steaming and sputtering in the mud. Down went all the sheet piling slowly into the water, till the sea rolled in over its top; but the cracking and bursting of the great struts within could still be heard as the splinters came floating to the surface. I have never seen a more disheartening wreck. It seems to me the imagination can never grasp the meaning of such a phrase, for instance, as "one hundred tons," nor grasp the immensity of the powers of earth and water, till he happens to upset their equilibrium and see them working in ponderous relentlessness against him.

But were the pier-builders in this instance discouraged? Not at all. They immediately despaired of making any money on the project, but not at all of finishing it. They diked off the sea, they set up and hosed off the derrick-car, began slowly lowering the water and replacing the broken timbers so far as they could; and then allowed the pit to flood again. Then, with the weight of the sea water in the pit to counterbalance the quicksand, they dug blindly and slowly through the water. The sand held; and taking courage at this, they began again to drive piles. Everybody watched breathlessly the first pile to see if the sand would again gush forth; but the weight of the water continued to hold it. So the piles were driven as the digging had been done—patiently and blindly through water. Once the "follower" pile slipped so that the great hammer struck down on nothing and the tall driver fell in a heap of kindling-wood, and the top man was carried away to the hospital; but they rebuilt and went on. Then came the diver in his helmet and leaden shoes to go down and cut off the piles at the right level. This was the most expensive process to the builders, but the most interesting to the onlookers; for to sit on the dike and watch the long pile-heads emerge miraculously from the deep and leap like porpoises in the air was more fun than a cock-fight. Finally came the filling with concrete through

the long pipe until enough solid concrete had been placed to equal the weight of water. Then the water could safely be pumped out and the worst was over.

This being merely a sample of the many difficulties of web-foot operations, it is small wonder that many schemes are afoot to make piles of concrete so that they will not have to be cut off at such low levels. A look at the advertising pages of any engineering magazine will show that much gray matter is being expended now in that direction. There are concrete piles that are driven by first driving a steel pile surrounded by a thin steel skin. The pile is pulled out again, leaving the skin to be filled with concrete. Others are made by driving a pipe with a steel point and then pulling it up. As it comes up, the steel point opens like a walnut, so that concrete can be rammed down through it to fill the hole. And there are piles that are moulded in boxes above ground and driven like wooden ones, save that the water is jetted down through a pipe in the middle of them. But all these have their disadvantages. Who can say, when a pile is made underground, that it is perfect? Who can say, when a pile is driven, that it is not cracked? Who can say why the famous concrete piles in Baltimore Bay are rotting at the water's surface? Concrete of the modern reinforced variety has been the cause of more bitter disappointment than any material we use. It will be difficult indeed to find a substitute for that good timber that Mr. Pinchot is so anxious for us to save, and that, when properly placed, will remain sound after steel is rusted, and concrete is crumbled, and gold itself is tarnished.

It will easily be seen that piling of any sort has its limitations. Supposing the Boston well-borer to be correct, then, if such a pit as we have described were dug in any city, obviously the whole neighborhood would fall into it were it not based on unyielding ground.

Foreseeing this possibility and its consequences, Mr. F. H. Kimball had the commendable obstinacy to insist that the foundations of the Manhattan Life Building in New York should go down to solid rock. Notwithstanding much adverse

criticism at the outset, his idea was finally accepted so completely that, during the following fifteen years, New York became the greatest deep-foundation city in the world. Nowhere else do men go dry-shod eighty-five feet below water-level without intervening barrier—as they did under the Mutual Life Building—and come back to tell about it. Nowhere else do caissons sink at the rate of two feet an hour, as they did on the sites of the North Trinity and United States Realty buildings. Nowhere else does one come upon complete portable air-compressing plants that will stand carting about a city, and when set down are capable of sucking in, compressing, and cooling a column of air a foot square at the rate of forty-five miles an hour. The New England coast has its six- and seven-masted schooners; but New York is the only known cruising-ground of the four-masted, four-boomed, electric-driven, rapid-hoisting, self-turning, portable derrick.

The colossal mistake by which New York was originally located is now of incalculable value to our engineering profession; the fact that it stands upon an island several sizes too small, surrounded and partly overlaid by sixty feet of mud, has developed more real engineers in America than all the technical colleges that we have.

In the caisson, as elsewhere in engineering, we find the principle foolishly simple, but the exigencies by the way both dangerous and difficult. Imagine a circular steel chimney, having two air-tight dampers in the middle of it, to be stood on end in soft ground. Obviously its weight, resting on its thin edge, would force it down like a pastry-cutter through dough. If, then, a man got into its interior and began digging and passing out the dirt in buckets or sacks, he could continue to lower the earth level inside and the chimney would continue to sink; but after three or four feet the water, which he could not remove faster than it ran in, would bring him to a halt. Now, a column or a stick of water an inch square and a foot high weighs about half a pound. Therefore, if air were pumped into the chimney below the dampers until it pressed half a pound on every square inch of it, the water would subside one foot; if five pounds, ten feet;

if fifty pounds, one hundred feet, and so on. The earth could be passed or hoisted out past the dampers without allowing the air to escape, just as a boat passes through a canal lock without wasting more than the lockful of water. But the unfortunate "sandhog," the crouching, sweating digger of earth inside the chimney, is seldom found who could stand fifty pounds of air on every square inch of him, inside and out, and there is the difficulty.

There are other difficulties. Suppose the air-pressure more than counterbalances the chimney—the caisson; then tons of iron or concrete must be piled on it to sink it; sometimes it is possible to use the future pier for this purpose. Suppose the air more than balances the water and blows out, causing a leak and the sudden imprisonment of Mr. Sandhog. Suppose, on the other hand, that through the breakage of a pipe or the explosion of a cylinder, it falls below normal. There again is danger. It is all danger, in a way, until the caisson is safely down on hard rock and filled with concrete. When we arrive at a habitable structure like the Metropolitan Tower, seven hundred feet high, standing ankle-deep in sixty feet of mud, with nearly four thousand tons bearing on every ankle, we see that man is "monkeying" with weights and balances so enormous that they outrun his imagination. Mathematics is his only medium for arriving at them.

More baffling still, the constitution and endurance of Mr. Sandhog himself cannot be scientifically determined. He may, at any moment, with the pressure of three additional atmcspheres upon him drop with heart failure, or be struck with paralysis, or come out of his caisson, after a brief hour and a half's work, stone-deaf for the rest of his days. All miscalculations, oversights, accidents, and blunders in this business are payable in human life. No large undertaking of this sort is without its tragedy, and one has but to stop and read the familiar little tablet on Brooklyn Bridge to be set thinking of the prices we have to pay for the things we have to have.

Yet, notwithstanding the difficulties encountered by the way and the very rapid development of his art, the modern web-

foot has carried on his operations so scientifically that to-day we have the astonishing but perfectly sane statement of Mr. O. F. Semsch, the designer of the Singer Building frame, that, given a lot two hundred feet square *and* the trifling sum of $60,000,000, he could erect a building or tower two thousand feet high which would stand perfectly firm against sinking or blowing over, and be well within all the building ordinances of the city.

In order to appreciate the great jump-off from ancient custom that had to be made in order to accomplish these things, we need take only the most superficial glance at the older structures. The Pyramids are securely founded on high and dry rock; therefore above reproach. Most of the Roman edifices are also on hills. The Tiber, being an intermittent stream, enabled the Romans to build a few good bridges during dry seasons; but the Forum, being on marshland, is an engineering botch, and the Cloaca Maxima so persistently apt to get stopped up that for hundreds of years the whole works were abandoned and used for a dump. Going a little further, we have the leaning towers of Pisa and Bologna, not to be compared in weight to a large modern factory chimney, yet able to show us how lamentably weak the old fellows were the minute they got a bit bogged; and in Venice we see the most striking example of how an entire city, although beautifully architectured, was never properly foundationed.

The costly buildings of Chicago, standing on shallow grillage and sinking so many inches a year, serve to emphasize at what a late date builders still hesitated to venture into the unstable depths.

Considering, then, the courageous jump-off from all precedent and established custom that the web-foot engineer has had to make, it is not surprising to find that the "father of civil engineering" in modern times was himself a pioneer web-foot. John Rennie was originally a mill constructor. But when the tide washed the foundations out from under his mills at Blackfriars Bridge, he was forced into matters of a larger sort. He earned his title by draining off that part of England which the appro-

priately named River Ouse had made into a hopeless swamp (a job that baffled even the great Cromwell), thereby furnishing the first and best example of the web-foot's third problem, wherein, by a system of dikes and ditches, he "un-waters" the land and renders it fit for cultivation. The magnificent Waterloo Bridge across the Thames is also his work,—his monument,—and when one looks upon this and the adjoining massive structures, which better than anything else portray the true solidity and grandeur of the English people, it is hard to believe that they are all standing knee-deep in river mud.

Rennie has his engineering descendants in every large modern city—in almost every large project of any kind; but especially are they to be found in our tallest, heaviest city of all—men far more worthy to be proud of than the world's records they have broken, or the inventions they have made: Mr. J. T. O'Rourke, who proposed the first circular caisson and invented a way to remove the roof or partition immediately over Mr. Sandhog's head so as to render the concrete pier one solid piece instead of two; Mr. John W. Doty and Mr. Daniel E. Moran, who simplified it further, making the future concrete pier serve to sink itself and arranging trap doors of such lightning action that the bucket and its muddy contents make a trip every minute; Mr. T. Kennard Thomson, who designs the four-masted derricks and whom I suspect of having everything to do with the speed records made in sinking caissons; Mr. Alfred Noble and Mr. Charles M. Jacobs, under whose supervision the East River and North River tunnels were designed; Mr. Samuel Rea, who passed upon all the plans, and directed the entire work; Mr. E. W. Moir, who personally supervised its execution: to say nothing of the assistants and resident engineers—Harrison, Brace, Mason, Woodward, Japp, Manton, who "slept on the job," worried over it, perspired over it, dreamed of it in whatever sleep they were fortunate enough to get. It is they whom I have respectfully termed web-foot engineers, who have transformed a small river-girt, rock-backed, swamp-covered scarcely habitable island, originally worth twenty-four dollars, into what is now, in some respects, the most livable, though in other

respects the most unlivable, but at all events the most lived upon, most densely populated, richest spot under the sun.

QUESTIONS AND EXERCISES

The foregoing selection further illustrates problems of adaptation. The writer is trying to present in terms of popular experience some engineering problems which, either from the very technical vocabulary in which they are usually expressed, or from the intricate nature of the material involved, generally remain unintelligible to the average man.

1. What does the writer attempt to do in this selection? Is he concerned with great accuracy or thoroughness? Are there any points at which his explanations are not entirely clear?

2. Into what divisions does the piece fall? How is the subject-matter proportioned?

3. For what sort of readers is the piece intended? Is the vocabulary suited to such readers? Note the cases in which the author makes his descriptions of engineering contrivances clear by means of comparisons.

Exercise 1. Explain clearly and connectedly the problems of the quarter-back, or the half-back, or the pitcher.

Exercise 2. Write an explanation of some of the new methods of mining, or of some new method of manufacturing some article.

Exercise 3. Write upon one of the following topics:

Shooting oil wells.
Construction of a sky-scraper.
Constructing a suspension bridge.
How flagstaffs are painted.

Exercise 4. Explain clearly and interestingly, avoiding technical language and using familiar comparisons, some of the problems and methods connected with the following:

Bridge-building.
Railway construction.
Digging a canal.
Long distance transmission of electricity.
Fire protection of manufacturing plants.

TWO KINDS OF EDUCATION FOR ENGINEERS[1]

JOHN BUTLER JOHNSON

EDUCATION may be defined as a means of gradual emancipation from the thraldom of incompetence. Since incompetence leads of necessity to failure, and since competence alone leads to certain success, in any line of human endeavor, and since the natural or uneducated man is but incompetence personified, it is of supreme importance that this thraldom, or this enslaved condition in which we are all born, should be removed in some way. While unaided individual effort has worked, and will continue to work marvels, in rare instances in our so-called self-made men, these recognized exceptions acknowledge the rule that mankind in general must be aided in acquiring this complete mastery over the latent powers of head, heart, and hand. These formal aids in this process of emancipation are found in the grades of schools and colleges with which the children of this country are now blessed beyond those of almost any other country or time. The boys or girls who fail to embrace these emancipating opportunities to the fullest extent practicable, are thereby consenting to degrees of incompetence and their corresponding and resulting failures in life, which they have had it in their power to prevent. This they will ultimately discover to their chagrin and even grief, when it is too late to regain the lost opportunities.

There are, however, two general classes of competency which I wish to discuss to-day, and which are generated in the schools. These are, *Competency to Serve*, and *Competency to Appreciate and Enjoy*.

By competency to serve is meant that ability to perform one's due proportion of the world's work which brings to society a common benefit, and which makes of this world a continually better home for the race, and which tends to fit the race for that immortal life in which it puts its trust.

[1] An address delivered before the College of Engineering, University of Wisconsin. Reprinted by permission of Mrs. Phoebe E. Johnson.

By competency to appreciate and enjoy is meant that ability to understand, to appropriate, and to assimilate those great personal achievements of the past and present in the fields of the true, the beautiful, and the good, which brings into our lives a kind of peace, and joy, and gratitude which can be found in no other way.

It is true that all kinds of elementary education contribute alike to both of these ends, but in the so-called higher education it is too common to choose between them rather than to include them both. Since it is only service which the world is willing to pay for, it is only those competent and willing to serve a public or private utility who are compensated in a financial way. It is the education which brings a competency to serve, therefore, which is often called the utilitarian, and sometimes spoken of contemptuously as the bread-and-butter, education. On the other hand, the education which gives a competency to appreciate and to enjoy is commonly spoken of as a cultured education. As to which kind of education is the higher and nobler, if they must be contrasted, it all depends on the point of view. If personal pleasure and happiness is the chief end and aim in life, then for that class of persons who have no disposition to serve, the cultural education is the more worthy of admiration and selection (conditioned of course on the bodily comforts being so far provided for as to make all financial compensations of no object to the individual). If, however, service to others is the most worthy purpose in life, and if in addition such service brings the greatest happiness, then that education which develops the ability to serve, in some capacity, should be regarded as the higher and more worthy. This kind of education has the further advantage that the money consideration it brings makes its possessor a self-supporting member of society instead of a drone or parasite which those people must be who cannot serve. I never could see the force of the statement that "they also serve who only stand and wait." It is possible they may serve their own pleasures, but if this is all, the statement should be so qualified.

The higher education which leads to a life of service has been

known as a professional education, as law, medicine, the ministry, teaching, and the like. These have long been known as the learned professions. A learned profession may be defined as a vocation in which scholarly accomplishments are used in the service of society or of other individuals for a valuable consideration. Under such a definition every new vocation in which a very considerable amount of scholarship is required for its successful prosecution, and which is placed in the service of others, must be held as a learned profession. And as engineering now demands fully as great an amount of learning, or scholarship, as any other, it has already taken a high rank among these professions, although as a learned profession it is scarcely half a century old. Engineering differs from all other learned professions, however, in this, that its learning has to do only with the inanimate world, the world of dead matter and force. The materials, the laws, and the forces of nature, and scarcely to any extent its life, is the peculiar field of the engineer. Not only is engineering pretty thoroughly divorced from life in general, but even with that society of which he is a part his professional life has little in common. His profession is so new it practically has no past, either of history or of literature, which merits his consideration, much less his laborious study. Neither do the ordinary social or political problems enter in any way into his sphere of operations. Natural law, dead matter, and lifeless force make up his working world, and in these he lives and moves and has his professional being. Professionally regarded, what to him is the history of his own or of other races? What have the languages and the literatures of the world of value to him? What interest has he in domestic or foreign politics, or in the various social and religious problems of the day? In short, what interest is there for him in what we now commonly include in the term "the humanities"? It must be confessed that in a professional way they have little or none. Except perhaps two other modern languages by which he obtains access to the current progress in applied science, he has practically no professional interest in any of these things. His structures are made no safer or more economical; his prime-

movers are no more powerful or efficient; his electrical wonders no more occult or useful; his tools no more ingenious or effective because of a knowledge of all these humanistic affairs. As a mere server of society, therefore, an engineer is about as good a tool without all this cultural knowledge as with it. But as a citizen, as a husband and father, as a companion, and more than all, as one's own constant, perpetual, unavoidable personality, the taking into one's life of a large knowledge of the life and thought of the world, both past and present, is a very important matter indeed, and of these two kinds of education, as they affect the life-work, the professional success, and the personal happiness of the engineer, I will speak more in detail.

I am here using the term engineer as including that large class of modern industrial workers who make the new application of science to the needs of modern life their peculiar business and profession. A man of this class may also be called an applied scientist. Evidently he must have a large acquaintance with such practical sciences as surveying, physics, chemistry, geology, metallurgy, electricity, applied mechanics, kinematics, machine design, power generation and transmission, structural designing, land and water transportation, etc., etc. And as a common solvent of all the problems arising in these various subjects he must have acquired an extended knowledge of mathematics, without which he would be like a sailor with neither compass nor rudder. To the engineer mathematics is a tool of investigation, a means to an end, and not the end itself. The same may be said of his physics, his chemistry, and of all his other scientific studies. They are all to be made tributary to the solution of problems which may arise in his professional career. His entire technical education, in fact, is presumably of the useful character, and acquired for specific useful ends. Similarly he needs a free and correct use of his mother tongue, that he may express himself clearly and forcibly both in speech and composition, and an ability to read both French and German, that he may read the current technical literature in the two other languages which are most fruitful in new and original technical matter.

It is quite true that the mental development, the growth of one's mental powers and the command over the same, which comes incidentally in the acquisition of all this technical knowledge, is of far more value than the knowledge itself, and hence great care is given in all good technical schools to the mental processes of the students, and to a thorough and logical method of presentation and of acquisition. In other words, while you are under our instruction it is much more important that you should think consecutively, rationally, and logically, than that your conclusions should be numerically correct. But as soon as you leave the school the exact reverse will hold. Your employer is not concerned with your mental development, or with your mental processes, so long as your results are correct, and hence we must pay some attention to numerical accuracy in the school, especially in the upper classes. We must remember, however, that the mind of the engineer is primarily a workshop and not a warehouse or lumber-room of mere information. Your facts are better stored in your library. Room there is not so valuable as it is in the mind, and the information, furthermore, is better preserved. Memory is as poor a reliance to the engineer as to the accountant. Both alike should consult their books when they want the exact facts. Knowledge alone is not power. The ability to use knowledge is a latent power, and the actual use of it is a power. Instead of storing your minds with useful knowledge, therefore, I will say to you, store your minds with useful tools, and with a knowledge only of how to use such tools. Then your minds will become mental workshops, well fitted for turning out products of untold value to your day and generation. Everything you acquire in your course in this college, therefore, you should look upon as mental tools with which you are equipping yourselves for your future careers. It may well be that some of your work will be useful rather for the sharpening of your wits and for the development of mental grasp, just as gymnastic exercise is of use only in developing your physical system. In this case it has served as a tool of development instead of one for subsequent use. Because all your knowledge here gained is to serve you as tools it must

be acquired quantitatively rather than qualitatively. First, last, and all the time, you are required to know not how simply, but how much, how far, how fast, to what extent, at what cost, with what certainty, and with what factor of safety. In the cultural education, where one is learning only to appreciate and to enjoy, it may satisfy the average mind to know that coal burned under a boiler generates steam which, entering a cylinder, moves a piston which turns the engine, and stop with that. But the engineer must know how many heat units there are in a pound of coal burned, how many of these are generated in the furnace, how many of them pass into the water, how much steam is consumed by the engine per horse-power per hour, and finally how much effective work is done by the engine per pound of coal fed to the furnace. Merely qualitative knowledge leads to the grossest errors of judgment and is of that kind of little learning which is a dangerous thing. At my summer home I have a hydraulic ram set below a dam, for furnishing a water supply. Nearby is an old abandoned water-power grist mill. A man and his wife were looking at the ram last summer and the lady was overheard to ask what it was for. The man looked about, saw the idle water-wheel of the old mill, and ventured the opinion that it must be used to run the mill! He knew a hydraulic ram when he saw it and he knew it was used to generate power, and that power would run a mill. *Ergo*, a hydraulic ram will run a mill. This is on a par with thousands of similar errors of judgment where one's knowledge is qualitative only. All engineering problems are purely quantitative from beginning to end, and so are all other problems, in fact, whether material, or moral, or financial, or commercial, or social, or political, or religious. All judgments passed on such problems, therefore, must be quantitative judgments. How poorly prepared to pass such judgments are those whose knowledge is qualitative only! Success in all fields depends very largely on the accuracy of one's judgment in foreseeing events, and in engineering it depends wholly on such accuracy. An engineer must see all around his problems, and take account of every contingency which can happen in the ordinary course of

events. When all such contingencies have been foreseen and provided against, then the unexpected cannot happen, as everything has been foreseen. It is customary to say "The unexpected always happens." This of course is untrue. What is meant is "It is only the unexpected which happens," for the very good reason that what has been anticipated has been provided against.

In order that knowledge may be used as a tool in investigations and in the solution of problems, it must be so used constantly during the period of its acquisition. Hence the large amount of drawing-room, field, laboratory, and shop practice introduced into our engineering courses. We try to make theory and practice go hand in hand. In fact we teach that theory is only a generalized practice. From the necessary facts, observed in special experiments or in actual practice, and which cover a sufficiently wide range of conditions, general principles are deduced from which effects of given like causes can be foreseen or derived, for new cases arising in practice. This is like saying, in surveying, that with a true and accurate hind-sight an equally true and accurate forward course can be run. Nearly all engineering knowledge, outside the pure mathematics, is of this experimental or empirical character, and we generally know who made the experiments, under what conditions, over what range of varying conditions, how accordant his results were, and hence what weight can be given to his conclusions. When we can find in our engineering literature no sufficiently accurate data, or none exactly covering the case in hand, we must set to work to make a set of experiments which will cover the given conditions, so as to obtain numerical factors, or possibly new laws, which will serve to make our calculations prove true in the completed structure or scheme. The ability to plan and carry out such crucial tests and experiments is one of the most important objects of an engineering college training, and we give our students a large amount of such laboratory practice. In all such work it is the absolute truth we are seeking and hence any guessing at data, or falsifying of records, or "doctoring" of the computations is of the nature of a professional crime.

Any copying of records from other observers, when students are supposed to make their own observations, is both a fraud upon themselves as well as dishonest to their instructor, and indicates a disposition of mind which has nothing in common with that of the engineer, who is always and everywhere a truth-seeker and truth-tester. The sooner such a person leaves the college of engineering the better for him and the engineering profession. Men in other professions may blunder or play false with more or less impunity. Thus the lawyer may advocate a bad cause without losing caste; a physician may blunder at will, but his mistakes are soon buried out of sight; a minister may advocate what he no longer believes himself, and feel that the cause justifies his course; but the mistakes of the engineer are quick to find him out and to proclaim aloud his incompetence. He is the one professional man who is obliged to be right, and for whom sophistry and self-deception are a fatal poison. But the engineer must be more than honest: he must be able to discern the truth. With him an honest motive is no justification. He must not only *believe* he is right: he must *know* that he is right. And it is one of the greatest elements of satisfaction in this profession, that it is commonly possible to secure in advance this almost absolute certainty of results. We deal with fixed laws and forces, and only so far as the materials used may be faulty, or of unknown character, or as contingencies could not be foreseen or anticipated, does a necessary ignorance enter into the problem.

It must not be understood, however, that with all of both theory and practice we are able to give our students in their four- or five-year course, that they will be full-fledged engineers when they leave us. They ought to be excellent material out of which, with a few years actual practice, they would become engineers of the first order. Just as a young physician must have experience with actual patients, and as a young lawyer must have actual experience in the courts, so must an engineer have experience with real problems before he can rightfully lay claim to the title of engineer. And in seeking this professional practice they must not be too choice. As a rule the higher

up one begins the sooner his promotion stops, and the lower down he begins the higher will he ultimately climb. The man at the top should know in a practical way all the work over which he is called upon to preside, and this means beginning at the bottom. Too many of our graduates refuse to do this, and so they stop in a middle position, instead of coming into the management of the business, which position is reserved for a man who knows it all from the bottom up. Please understand that no position is too menial in the learning of a business. But as your college training has enabled you to learn a new thing rapidly, you should rapidly master these minor details of any business, and in a few years you should be far ahead of the ordinary apprentice who went to work from the grammar or from the high school. The great opportunity for the engineer of the future is in the direction and management of our various manufacturing industries. We are about to become the world's workshop, and as competition grows sharper and as greater economies become necessary, the technically trained man will become an absolute necessity in the leading positions in all our industrial works. These are the positions hitherto held by men who have grown up with the business, but without technical training. They are being rapidly supplanted by technical men, who, however, must serve their apprenticeship in the business, from the bottom up. With this combination of theory and practice, and with the American genius for invention, and with our superb spirit of initiative and of independence, we are already setting a pace industrially which no other nation can keep, and which will soon leave all others hopelessly behind.

In the foregoing description of the technical education and work of the engineer, the engineer himself has been considered as a kind of human tool to be used in the interest of society. His service to society alone has been in contemplation. But as the engineer has also a personality which is capable of appreciation and enjoyment of the best this world has produced in the way of literature and art; as he is to be a citizen and a man of family; and moreover, since he has a conscious self with which he must always commune and from which he cannot

escape, it is well worth his while to see to it that this self, this husband and father, this citizen and neighbor, is something more than a tool to be worked in other men's interests, and that his mind shall contain a library, a parlor, and a drawing room, as well as a workshop. And yet how many engineers' minds are all shop and out of which only shop-talk can be drawn! Such men are little more than animated tools, worked in the interest of society. They are liable to be something of a bore to their families and friends, almost a cipher in the social and religious life of the community, and a weariness to the flesh to their more liberal-minded professional brethren. Their lives are one continuous grind, which has for them doubtless a certain grim satisfaction, but which is monotonous and tedious in comparison with what they might have been. Even when valued by the low standard of money-making they are not nearly so likely to secure lucrative incomes as they would be with a greater breadth of information and worldly interest. They are likely to stop in snug professional berths which they find ready-made for them, under some sort of fixed administration, and maintain through life a subordinate relation to directing heads who with a tithe of their technical ability are yet able, with their worldly knowledge, their breadth of interests, and their fellowship with men, to dictate to these narrower technical subordinates, and to fix for them their fields of operation.

In order, therefore, that the technical man, who in material things knows what to do and how to do it, may be able to get the thing done and to direct the doing of it, he must be an engineer of men and of capital as well as of the materials and forces of nature. In other words he must cultivate human interests, human learning, human associations, and avail himself of every opportunity to further these personal and business relations. If he can make of himself a good business man, or as good a manager of men as he usually makes of himself in the field of engineering he has chosen, there is no place too great, and no salary too high for him to aspire to. Of such men are our greatest railroad presidents and general managers, and the directors of our largest industrial establishments.

While most of this kind of knowledge must also be acquired in actual practice, yet some of it can best be obtained in college. I shall continue to urge upon all young men who can afford it to either take the combined six-year college and engineering course, described in our catalogue, or the five-year course in the college of engineering, taking as extra studies many things now taught in our school of commerce. The one crying weakness of our engineering graduates is ignorance of the business, the social, and the political world, and of human interests in general. They have little knowledge in common with the graduates of our literary colleges, and hence often find little pleasure in such associations. They become clannish, run mostly with men of their class, take little interest in the commercial or business departments of the establishments with which they are connected, and so become more and more fixed in their inanimate worlds of matter and force. I beseech you, therefore, while yet students, to try to broaden your interests, extend your horizons now into other fields, even but for a bird's-eye view, and profit, so far as possible, by the atmosphere of universal knowledge which you can breathe here through the entire period of your college course. Try to find a chum who is in another department; go to literary societies; haunt the library; attend the available lectures in literature, science, and art; attend the meetings of the Science Club; and in every way possible, with a peep here and a word there, improve to the utmost these marvellous opportunities which will never come to you again. Think not of tasks; call no assignments by such a name. Call them opportunities, and cultivate a hunger and thirst for all kinds of humanistic knowledge outside your particular world of dead matter, for you will never again have such an opportunity, and you will be always thankful that you made good use of this, your one chance in a lifetime.

For your own personal happiness, and that of your immediate associates, secure in some way, either in college or after leaving the same, an acquaintance with the world's best literature, with the leading facts of history, and with the biographies of many of the greatest men in pure and applied science, as well

as of statesmen and leaders in many fields. With this knowledge of great men, great thoughts, and great deeds, will come that lively interest in men and affairs which is held by educated men generally, and which will put you on an even footing with them in your daily intercourse. This kind of knowledge, also, elevates and sweetens the intellectual life, leads to the formation of lofty ideals, helps one to a command of good English, and in a hundred ways refines, and inspires to high and noble endeavor. This is the cultural education leading to appreciation and enjoyment man is assumed to possess.

Think not, however, that I depreciate the peculiar work of the engineering college. It is by this kind of education alone that America has already become supreme in nearly all lines of material advancement. I am only anxious that the men who have made these things possible shall reap their full share of the benefits.

In conclusion let me congratulate you on having selected courses of study which will bring you into the most intimate relations with the world's work of your generation. All life to-day is one endless round of scientific applications of means to ends, but such applications are still in their infancy. A decade now sees more material progress than a century did in the past. Not to be scientifically trained in these matters is equivalent to-day to a practical exclusion from all part and share in the industrial world. The entire direction of the world's industry and commerce is to be in your hands. You are also charged with making the innumerable new discoveries and inventions which will come in your generation and almost wholly through men of your class. The day of the inventor, ignorant of science and of nature's laws, has gone by. The mere mechanical contrivances have been pretty well exhausted. Henceforth profitable invention must include the use or embodiment of scientific principles with which the untrained artisan is unacquainted. More and more will invention be but the scientific application of means to ends, and this is what we teach in the engineering schools. Already our patent office is much puzzled to distinguish between engineering and inven-

tion. Since engineering proper consists in the solution of new problems in the material world, and invention is likewise the discovery of new ways of doing things, they cover the same field. But an invention is patentable, while an engineering solution is not. Invention is supposed in law to be an inborn faculty by which new truth is conceived by no definable way of approach. If it had not been reached by this particular individual it is assumed that it might never have been known. An engineering solution is supposed, and rightly, to have been reached by logical processes, through known laws of matter, and force, and motion, so that another engineer, given the same problem, would probably have reached the same or an equivalent result. And this is not patentable. Already a very large proportion of the patents issued could be nullified on this ground if the attorneys only knew enough to make their case. More and more, therefore, are the men of your class to be charged with the responsibility and to be credited with the honor of the world's progress, and more and more is the world's work to be placed under your direction. The world will be remade by every succeeding generation, and all by the technically educated class. These are your responsibilities and your honors. The tasks are great and great will be your rewards. That you may fitly prepare yourself for them is the hope and trust of your teachers in this college of engineering.

I will close this address by quoting Professor Huxley's definition of a liberal education. Says Huxley: "That man, I think, has had a liberal education who has been so trained in youth that his body is the ready servant of his will, and does with ease and pleasure all the work that, as a mechanism, it is capable of; whose intellect is a clear, cold, logic-engine, with all its parts of equal strength, and in smooth working order; ready, like a steam engine, to be turned to any kind of work, and spin the gossamers as well as forge the anchors of the mind; whose mind is stored with a knowledge of the great and fundamental truths of Nature and of the laws of her operations; one who, no stunted ascetic, is full of life and fire, but whose passions are trained to come to heel by a vigorous will, the

servant of a tender conscience; who has learned to love all beauty, whether of nature or of art, to hate all vileness, and to respect others as himself.

"Such an one and no other, I conceive, has had a liberal education; for he is, as completely as a man can be, in harmony with Nature. He will make the best of her, and she of him. They will get on together rarely; she as his ever-beneficent mother; he as her mouthpiece, her conscious self, her minister and interpreter."

QUESTIONS AND EXERCISES

This selection is an address delivered before the students of the College of Engineering in the University of Wisconsin. Though somewhat faulty in detail, it is admirable in outline, and vigorous and suggestive in treatment. The address may be studied as a general review of the principles of organic structure exemplified in the first group of selections as well as of the principles of adaptation emphasized in the two preceding selections.

1. After reading the piece in its entirety, make a careful outline of its thought, and express the leading idea of the address in a single sentence.

2. Does the address begin too abruptly? Is there any need of an introduction? Does the first paragraph contain in germ the rest of the address? On what principle is the division of the subject made in paragraph two? Is the division satisfactory?

3. Does the author in the development of his topics proceed inductively or deductively; that is, does he first present his facts and then draw his conclusions, or does he proceed somewhat dogmatically in the opposite way?

4. How effective is the conclusion?

5. Pick out any details that indicate the kind of audience addressed. What changes in arrangement, phrasing, and choice of detail would you expect if the address were intended for high school boys who were not seriously considering going to college?

Exercise 1. Write upon one of the following subjects:

Two kinds of athletics for colleges.

Two ideas of the meaning of "advancement in life."

Two ways of using books in gathering composition material.

The ideal versus the real newspaper.

The negro of the South and the negro of the North.

Two kinds of education for lawyers, ministers, doctors, or any other profession.

Exercise 2. The problem of adaptation requires the cultivation of a power of sympathetic imagination that will enable a writer or speaker to analyze the intellectual situation of his hearers or readers. This power may be developed by writing such descriptions of audiences as are called for in the following exercises. The description should be as detailed as possible.

Describe a self-made business man's attitude towards college graduates.

Describe the attitude of a college faculty towards hazing.

Exercise 3. It is supposed that you are to appear before a city council to advocate municipal ownership of the electric lighting system or the water-works. Characterize the various types of mind that you may be called upon to meet.

LAWS OF PARAGRAPH-MAKING

AMERICANISM: AN ATTEMPT AT A DEFINITION[1]

BRANDER MATTHEWS

THERE are many words in circulation among us which we understand fairly well, which we use ourselves, and which we should, however, find it difficult to define. I think that *Americanism* is one of these words; and I think also it is well for us to inquire into the exact meaning of this word, which is often most carelessly employed. More than once of late have we heard a public man praised for his "aggressive Americanism," and occasionally we have seen a man of letters denounced for his "lack of Americanism." Now what does the word really mean when it is thus used?

It means, first of all, a love for this country of ours, an appreciation of the institutions of this nation, a pride in the history of this people to which we belong. And to this extent *Americanism* is simply another word for *patriotism*. But it means also, I think, more than this: it means a frank acceptance of the principles which underlie our government here in the United States. It means, therefore, a faith in our fellowman, a belief in liberty and in equality. It implies, further, so it seems to me, a confidence in the future of this country, a confidence in its destiny, a buoyant hopefulness that the right will surely prevail.

In so far as Americanism is merely patriotism, it is a very good thing. The man who does not think his own country the finest in the world is either a pretty poor sort of a man or else he has a pretty poor sort of a country. If any people have

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not patriotism enough to make them willing to die that the nation may live, then that people will soon be pushed aside in the struggle of life, and that nation will be trampled upon and crushed; probably it will be conquered and absorbed by some race of a stronger fibre and of a sterner stock. Perhaps it is difficult to declare precisely which is the more pernicious citizen of a republic when there is danger of war with another nation—the man who wants to fight, right or wrong, or the man who does not want to fight, right or wrong; the hot-headed fellow who would plunge the country into a deadly struggle without first exhausting every possible chance to obtain an honorable peace, or the cold-blooded person who would willingly give up anything and everything, including honor itself, sooner than risk the loss of money which every war surely entails. "My country, right or wrong," is a good motto only when we add to it, "and if she is in the wrong, I'll help to put her in the right." To shrink absolutely from a fight where honor is really at stake, this is the act of a coward. To rush violently into a quarrel when war can be avoided without the sacrifice of things dearer than life, this is the act of a fool.

True patriotism is quiet, simple, dignified; it is not blatant, verbose, vociferous. The noisy shriekers who go about with a chip on their shoulders and cry aloud for war upon the slightest provocation belong to the class contemptuously known as "Jingoes." They may be patriotic,—and as a fact they often are,—but their patriotism is too frothy, too hysteric, too unintelligent, to inspire confidence. True patriotism is not swift to resent an insult; on the contrary, it is slow to take offence, slow to believe that an insult could have been intended. True patriotism, believing fully in the honesty of its own acts, assumes also that others are acting with the same honesty. True patriotism, having a solid pride in the power and resources of our country, doubts always the likelihood of any other nation being willing carelessly to arouse our enmity.

In so far, therefore, as Americanism is merely patriotism it is a very good thing, as I have tried to point out. But Americanism is something more than patriotism. It calls not only

for love of our common country, but also for respect for our fellow-man. It implies an actual acceptance of equality as a fact. It means a willingness always to act on the theory, not that "I'm as good as the other man," but that "the other man is as good as I am." It means levelling up rather than levelling down. It means a regard for law, and a desire to gain our wishes and to advance our ideas always decently and in order, and with deference to the wishes and the ideas of others. It leads a man always to acknowledge the good faith of those with whom he is contending, whether the contest is one of sport or of politics. It prevents a man from declaring, or even from thinking, that all the right is on his side, and that all the honest people in the country are necessarily of his opinion.

And, further, it seems to me that true Americanism has faith and hope. It believes the world is getting better, if not year by year, at least century by century; and it believes also that in this steady improvement of the condition of mankind these United States are destined to do their full share. It holds that, bad as many things may seem to be to-day, they were worse yesterday, and they will be better to-morrow. However dark the outlook for any given cause may be at any moment, the man imbued with the true spirit of Americanism never abandons hope and never relaxes effort; he feels sure that everything comes to him who waits. He knows that all reforms are inevitable in the long run; and that if they do not finally establish themselves it is because they are not really reforms, though for a time they may have seemed to be.

And a knowledge of the history of the American people will supply ample reasons for this faith in the future. The sin of negro-slavery never seemed to be more secure from overthrow than it did in the ten years before it was finally abolished. A study of the political methods of the past will show that there has been immense improvement in many respects; and it is perhaps in our political methods that we Americans are most open to censure. That there was no deterioration of the moral stamina of the whole people during the first century of the American republic any student can make sure of by comparing

the spirit which animated the inhabitants of the thirteen Colonies during the Revolution with the spirit which animated the population of the Northern states (and of the Southern no less) during the Civil War. We are accustomed to sing the praises of our grandfathers who won our independence, and very properly; but our grandchildren will have also to sing the praises of our fathers who stood up against one another for four years of the hardest fighting the world has ever seen, bearing the burdens of a protracted struggle with an uncomplaining cheerfulness which was not a characteristic of the earlier war.

True Americanism is sturdy but modest. It is as far removed from "Jingoism" in times of trouble as it is from "Spread-Eagleism" in times of peace. It is neither vainglorious nor boastful. It knows that the world was not created in 1492, and that July 4, 1776, is not the most important date in the whole history of mankind. It does not overestimate the contribution which America has made to the rest of the world, nor does it underestimate this contribution. True Americanism, as I have said, has a pride in the past of this great country of ours, and a faith in the future; but none the less it is not so foolish as to think that all is perfection on this side of the Atlantic, and that all is imperfection on the other side.

It knows that some things are better here than anywhere else in the world, that some things are no better, and that some things are not so good in America as they are in Europe. For example, probably the institutions of the nation fit the needs of the population with less friction here in the United States than in any other country in the world. But probably, also, there is no other one of the great nations of the world in which the government of the large cities is so wasteful and so negligent.

True Americanism recognizes the fact that America is the heir of the ages, and that it is for us to profit as best we can by the experience of Europe, not copying servilely what has been successful in the old world, but modifying what we borrow in accord with our own needs and our own condi-

tions. It knows, and it has no hesitation in declaring, that we must always be the judges ourselves as to whether or not we shall follow the example of Europe. Many times we have refused to walk in the path of European precedent, preferring very properly to blaze out a track for ourselves. More often than not this independence was wise, but now and again it was unwise.

Finally, one more quality of true Americanism must be pointed out. It is not sectional. It does not dislike an idea, a man, or a political party because that idea, that man, or that party comes from a certain part of the country. It permits a man to have a healthy pride in being a son of Virginia, a citizen of New York, a native of Massachusetts, but only on condition that he has a pride still stronger that he is an American, a citizen of the United States. True Americanism is never sectional. It knows no north and no south, no east and no west. And as it has no sectional likes and dislikes, so it has no international likes and dislikes. It never puts itself in the attitude of the Englishman who said, "I've no prejudices, thank Heaven, but I do hate a Frenchman!" It frowns upon all appeals to the former allegiance of naturalized citizens of this country; and it thinks that it ought to be enough for any man to be an American without the aid of the hyphen which makes him a British-American, an Irish-American, or a German-American.

True Americanism, to conclude, feels that a land which bred Washington and Franklin in the last century, and Emerson and Lincoln in this century, and which opens its schools wide to give every boy the chance to model himself on these great men, is a land deserving of Lowell's praise as "a good country to live in, a good country to live for, and a good country to die for."

QUESTIONS AND EXERCISES

"The two constant aims, clearness and interest," says Professor C. S. Baldwin in *Writing and Speaking*, "and the three constant principles, unity, emphasis, and coherence, once grasped in short compositions, there remains no new doctrine to be learned, nothing that does not follow from these. They contain all rhetoric in a

nutshell. But there remain many problems to be solved practically, problems that arise as soon as one attempts to speak or write at greater length." And many of these new problems have to do with paragraphing, to the study of which we turn in this selection.

1. How are the paragraphs made evident in outward form?

2. How many main points in this selection? State them in your own words in an outline or diagram.

3. Does the paragraphing correspond to these main topics; that is, are there an equal number of paragraphs and main topics? Give reasons for any disparity that you may find in this matter.

4. What then is your conclusion in regard to the purpose and value of the paragraphs as markers of the thought-divisions of the piece? Of what value would the paragraphs be to the writer? To the reader?

5. Several kinds of paragraphs are to be distinguished according to the office they perform in the whole piece of writing. A convenient classification is (1) *introductory* paragraphs in which the subject of the composition is stated; (2) *outlining* paragraphs in which a proposed line of treatment is briefly set forth; (3) *summarizing* paragraphs in which a review or recapitulation of points discussed is given; (4) *transitional* paragraphs used to pass from one part of a discussion to another and to show the connection of parts; (5) *concluding* paragraphs which gather into themselves the force of all the preceding paragraphs; (6) *developing* paragraphs which treat in detail a certain part of the subject. The developing paragraph is the type most frequently found. It is, in fact, the normal form of paragraph to which the laws of paragraph structure are most applicable, the other types being abnormal types and more or less loosely constructed. Determine the function of each of the paragraphs in this selection. What seem to you to be the essentials of a good introduction? Does the introductory paragraph in this selection fulfil the requirements of a good introduction? What are the essentials of a good conclusion? Are they fulfilled by the concluding paragraph of this selection?

6. From the nature of the paragraph as marking a distinct stage of a composition set off to be discussed by itself it follows that a paragraph must not confuse the reader by containing more than its allotted portion of the material, either by transgressing on the province of another paragraph or by digressions and irrelevant matter. A good way to ascertain whether a paragraph fulfils this requirement of unity is to see whether the gist of it can easily be summed up in a single sentence. Determine in this way whether the paragraphs in

this piece are well unified. Has the writer himself formulated the leading ideas of his paragraphs in topic-sentences appearing in the paragraphs themselves?

7. Make outlines of particular paragraphs, the seventh, for instance, to determine whether the various details mentioned are arranged upon a preconceived plan or are left to haphazard.

8. Point out the words in the various sentences that connect with what is before or after. Find paragraphs in which the sentences are fashioned on pretty much the same lines throughout. Discuss the value of this device of parallel structure, as it is called, in keeping up the connection of thought in a paragraph. Break up the parallel structure in some of these passages. Does the paragraph lose in smoothness of flow of thought? Has Professor Matthews used this device so frequently that it becomes a mannerism?

Exercise 1. In the selection from Mill, pp. 125 ff, some of the paragraphs are unduly long. Indicate the places at which new paragraphs might be made.

Exercise 2. Some of the paragraphs in Johnson's *Two Kinds of Education for Engineers* are too long; others seem to be rather short. Revise the paragraphing of this selection.

Exercise 3. Develop several of the following topic-sentences into well-constructed paragraphs of about 200 words. Until proficiency in effective paragraph structure is attained, it will be best to write paragraphs that conform rather rigidly to the typical scheme of paragraph structure. "The soldier must learn the drill code with scrupulous accuracy before he can move without confusion in free formation. The orator must know exactly the points he wishes to bring out before he dare speak with apparent informality. In all intellectual work, successful ease and freedom come after, not before a rigorous mental discipline. Therefore begin with paragraphs whose logical development is obvious."[1] Let the paragraphs begin with a statement of the central thought. Let the succeeding sentences amplify this thought, each containing some word to show its relation to the neighboring sentences, and each so phrased as to throw similar thoughts into similar constructions. Let the paragraph end with a sentence or group of sentences that binds the thought of the whole together and leave before the reader, in completed form, the effect intended.

The best business methods are nothing but applied honesty.

[1] Canby and others. *English Composition in Theory and Practice*, pp. 85–86 (The Macmillan Company).

Fashions change with bewildering rapidity.
Books are sometimes better companions than persons.
Experience is a dear school.
Railroads and telegraphs make the world smaller.
All great men have had their moments of folly.
Every boy should have a workshop.
Seed corn should be selected by an expert.
Most of us are careless in our enunciation.
The national government is a complex piece of machinery.
No pursuit is ignoble if conscientiously followed.
The newspaper continues to encroach on the magazine.
One is frequently surprised at the intelligence which the lower animals show.
Even in the smallest towns you will find a specimen of almost every grade of humanity.
The most influential student does not always receive the highest marks.
The rural free delivery has been a great boon to the farmer.
The telephone may be a nuisance as well as a convenience.
It is false charity to give to every stranger that asks for aid.

THE RELATIVITY OF ALL KNOWLEDGE[1]

HERBERT SPENCER

If, when walking through the fields some day in September, you hear a rustle a few yards in advance, and on observing the ditch side where it occurs, see the herbage agitated, you will probably turn toward the spot to learn by what this sound and motion are produced. As you approach there flutters into the ditch, a partridge; on seeing which your curiosity is satisfied—you have what you call an *explanation* of the appearances. The explanation, mark, amounts to this: that whereas throughout life you have had countless experiences of disturbance among small stationary bodies, accompanying the movement of other bodies among them, and have generalized the relation

[1] Reprinted from *First Principles*, by permission of Messrs. D. Appleton & Co.

between such disturbances and such movements, you consider this particular disturbance explained, on finding it to present an instance of the like relation. Suppose you catch the partridge; and, wishing to ascertain why it did not escape, examine it, and find at one spot a slight trace of blood upon its feathers. You now *understand*, as you say, what has disabled the partridge. It has been wounded by a sportsman—adds another case to the many cases already seen by you, of birds being killed or injured by the shot discharged at them from fowling-pieces. And in assimilating this case to other such cases consists your understanding of it. But now, on consideration, a difficulty suggests itself. Only a single shot has struck the partridge, and that not in a vital place: the wings are uninjured, as are also those muscles which move them; and the creature proves by its struggles that it has abundant strength. Why then, you inquire of yourself, does it not fly? Occasion favoring, you put the question to an anatomist, who furnishes you with a *solution*. He points out that this solitary shot has passed close to the place at which the nerve supplying the wing-muscles of one side diverges from the spine; and that a slight injury to this nerve, extending even to the rupture of a few fibers, may, by preventing a perfect coördination in the actions of the two wings, destroy the power of flight. You are no longer puzzled. But what has happened?—what has changed your state from one of perplexity to one of *comprehension?* Simply the disclosure of a class of previously known cases, along with which you can include this case. The connection between lesions of the nervous system and paralysis of the limbs has been already many times brought under your notice; and you here find a relation of cause and effect that is essentially similar.

Let us suppose you are led on to make further inquiries concerning organic actions, which, conspicuous and remarkable as they are, you had not before cared to understand. How is respiration effected? you ask—why does air periodically rush into the lungs? The answer is that in the higher vertebrata, as in ourselves, influx of air is caused by an enlargement of the

thoracic cavity, due partly to depression of the diaphragm, partly to elevation of the ribs. But how does elevation of the ribs enlarge the cavity? In reply the anatomist shows you that the plane of each pair of ribs makes an acute angle with the spine; that this angle widens when the movable ends of the ribs are raised; and he makes you realize the consequent dilatation of the cavity by pointing out how the area of a parallelogram increases as its angles approach to right angles—you understand this special fact when you see it to be an instance of a general geometrical fact. There still arises, however, the question—why does the air rush into this enlarged cavity? To which comes the answer that, when the thoracic cavity is enlarged, the contained air, partially relieved from pressure, expands, and so loses some of its resisting power; that hence it opposes to the pressure of the external air a less pressure; and that as air, like every other fluid, presses equally in all directions, motion must result along any line in which the resistance is less than elsewhere; whence follows an inward current. And this *interpretation* you recognize as one, when a few facts of like kind, exhibited more plainly in a visible fluid such as water, are cited in illustration. Again, when it was pointed out that the limbs are compound levers acting in essentially the same way as levers of iron or wood, you might consider yourself as having obtained a partial *rationale* of animal movements. The contraction of a muscle, seeming before utterly unaccountable, would seem less unaccountable were you shown how, by a galvanic current, a series of soft iron magnets could be made to shorten itself, through the attraction of each magnet for its neighbors:—an alleged analogy which especially answers the purpose of our argument, since, whether real or fancied, it equally illustrates the mental illumination that results on finding a class of cases within which a particular case may possibly be included. And it may be further noted how, in the instance here named, an additional feeling of comprehension arises on remembering that the influence conveyed through the nerves to the muscles is, though not positively electric, yet a form of force nearly allied to the electric. Sim-

ilarly when you learn that animal heat arises from chemical combinations—when you learn that the absorption of nutrient fluids through the coats of the intestines is an instance of osmotic action—when you learn that the changes undergone by food during digestion are like changes artificially producible in the laboratory, you regard yourself as *knowing* something about the natures of these phenomena.

Observe now what we have been doing. Turning to the general question, let us note where these successive interpretations have carried us. We began with quite special and concrete facts. In explaining each, and afterwards explaining the more general facts of which they are instances, we have got down to certain highly general facts:—to a geometrical principle or property of space, to a simple law of mechanical action, to a law of fluid equilibrium—to truths in physics, in chemistry, in thermology, in electricity. The particular phenomena with which we set out have been merged in larger and larger groups of phenomena; and as they have been so merged, we have arrived at solutions that we consider profound in proportion as this process has been carried far. Still deeper explanations are simply further steps in the same direction. When, for instance, it is asked why the law of action of the lever is what it is, or why fluid equilibrium and fluid motion exhibit the relations which they do, the answer furnished by mathematicians consists in the disclosure of the principle of virtual velocities—a principle holding true alike in fluids and solids—a principle under which the others are comprehended. And similarly, the insight obtained into the phenomena of chemical combination, heat, electricity, etc., implies that a rationale of them, when found, will be the exposition of some highly general fact respecting the constitution of matter, of which chemical, electrical, and thermal facts are merely different manifestations.

Is this process limited or unlimited? Can we go on forever explaining classes of facts by including them in larger classes; or must we eventually come to a largest class? The supposition that the process is unlimited, were any one absurd enough to espouse it, would still imply that an ultimate explanation

could not be reached, since infinite time would be required to reach it. While the unavoidable conclusion that it is limited (proved not only by the finite sphere of observation open to us, but also by the diminution in the number of generalizations that necessarily accompanies increase of their breadth) equally implies that the ultimate fact cannot be understood. For if the successively deeper interpretations of nature which constitute advancing knowledge are merely successive inclusions of special truths in general truths, and of general truths in truths still more general, it obviously follows that the most general truth, not admitting of inclusion in any other, does not admit of interpretation. Manifestly, as the *most* general cognition at which we arrive cannot be reduced to a *more* general one, it cannot be understood. Of necessity, therefore, explanation must eventually bring us down to the inexplicable. The deepest truth which we can get at must be unaccountable. Comprehension must become something other than comprehension before the ultimate fact can be comprehended.

QUESTIONS AND EXERCISES

This selection is given its position under the study of the paragraph because it well exemplifies connection of sentences in the paragraph and the adjustment of the paragraph to its place in the whole composition. It also exemplifies the inductive arrangement of material.

1. Note the skilful way in which the abstruse subject-matter is presented. Show how Spencer begins with facts the simplest and most concrete, and then builds up gradually to the complex. Compare this method of developing a composition *inductively*, that is, by first presenting facts and then drawing conclusions from them, with the *deductive* method, which proceeds somewhat dogmatically in the opposite way, as for example in Brander Matthews' *Americanism*. Discuss whether the following quotation explains the best occasion for the use of each of these modes of development. "If my object is to convince you of a general truth, or to impress you with a feeling which you are not already prepared to accept, it is obvious that the more effective method is the inductive, which leads your mind upon a culminating wave of evidence or emotion to the very point I aim at. But the deductive method is best when I wish to direct the light of familiar truths and roused emotions upon new particulars, or upon

details in unsuspected relation to these particulars; and when I wish the attention to be absorbed by these particulars which are of interest in themselves, not upon the general truths which are of no present interest except as far as they light up these details. A growing thought requires the inductive exposition, an applied thought the deductive."—(Lewes, *Principles of Success in Literature.*)

2. In order that the explanation in the closing paragraphs may be conclusive, the first part of the discussion must be perfectly clear. Clearness in this case also implies not one but many easily intelligible examples, since the final explanation is dependent upon showing that the process by which comprehension is effected is always the same. Are the examples well chosen? Are they sufficiently representative of all knowledge? Does each paragraph mark a distinct step in the development of the whole?

3. The coherence of this selection is admirable. This is secured by the skilful plan underlying the whole piece just pointed out; but it is very materially aided by being confirmed by words of transition. These connective or link-words complete the chain of coherence. What are the link-words for the paragraphs? Not only is there this clear connection between the paragraphs, but it is also to be found between the sentences of each paragraph. In almost every sentence there is some word or phrase which echoes a preceding sentence or looks ahead to the sentence or sentences to follow. Make a careful study of all such connective words. Compare the number of connectives used within the paragraphs of this piece with that employed in some other selection in this book. Has Spencer any other devices than by link-words for carrying on the thought within the paragraphs? From cases where the link has been omitted what rule can be deduced for such omission?

4. Discuss the following statement of De Quincey regarding the importance of connection between the sentences of the paragraph: "It is the *relation* of sentences, in what Horace terms their '*junctura*,' that the true life of composition resides. The mode of their *nexus* —the way in which one sentence is made to arise out of another, and to prepare the opening for a third,—this is the great loom in which the textile process of the moving intellect reveals itself and prospers."—(*Essay on Language.*)

Exercise 1. Criticise to the minutest detail the following student paragraph on slang; then rewrite, retaining as much of the original phraseology as possible, but rearranging freely and adding whatever transitions are necessary.

"Although slang is used a great deal, its use is most common among people between the ages of fifteen and twenty years. It enables people to express themselves more easily and with fewer words than they could without it, and in this way it is helpful. But it has many disadvantages. The speaker may have a perfectly clear idea, but if he uses slang terms to express it, it is apt to be misunderstood. Slang terms are continually being found, and thus different terms are being used in different parts of the country. I think a limited use of slang is all right, but the speaker should be sure that his hearer will understand him, and he should be able to express himself in good language to people who would not be likely to understand the slang term."

Exercise 2. In the following paragraph are four different subjects of remark: *a*, several pious individuals; *b*, improvement of the condition of criminals; *c*, the new prisons; *d*, the old prisons. These are denoted, as often as they occur in the paragraph, by the letters *a*, *b*, *c*, and *d* respectively. Rewrite the paragraph, substituting for these letters proper words and phrases of explicit reference. Take care to introduce some variety into the reference-words, and see that the thought grows in repetition.

"Some years ago several pious individuals undertook to ameliorate the condition of the prisons. The public was excited by the statements which *a* put forward, and *b* became a very popular undertaking. New prisons were built; and, for the first time, the idea of *b* formed a part of prison discipline. But *b*, in which the public had taken so hearty an interest, and which the exertions of the citizens had irresistibly accelerated, could not be completed in a moment. While *c* were being erected (and it was the pleasure of the majority *c* should be terminated with all possible celerity), *d* existed, which still contained a great number of offenders. *d* became more unwholesome and more corrupt in proportion as *c* were beautified and improved, forming a contrast which may be readily understood. The majority were so eagerly employed in founding *c* that *d* were forgotten; and as the general attention was diverted to *c*, the care which had hitherto been bestowed upon *d* ceased. The salutary regulations of discipline were first relaxed, and afterwards broken; so that in the immediate neighborhood of *c*, *d* might be met with."[1]

Exercise 3. Sum up the results of this general study of the para-

[1] Taken from Scott and Denney's *Composition-Rhetoric.*

graph in a paragraph of 200 words with the title "The Essentials of a Good Paragraph."

Exercise 4. Write a paragraph on one of the following subjects. Be careful about the use of connecting words and phrases.

How seeds are scattered by the wind.

Usefulness of insects.

The strange tricks memory plays us.

Boorishness in public servants.

The uses of work.

The difficulty of being unprejudiced.

Exercise 5. Explain some proverb or maxim in a paragraph of 200 words, such as:

A stitch in time saves nine.

Make hay while the sun shines.

The more hurry, the less speed.

PRINCIPLES OF SENTENCE CONSTRUCTION

THE IDEAL HISTORIAN[1]

WHILE our historians are practicing all the arts of controversy, they miserably neglect the art of narration, the art of interesting the affections and presenting pictures to the imagination. That a writer may produce these effects without violating truth is sufficiently proved by many excellent biographical works. The immense popularity which well-written books of this kind have acquired deserves the serious consideration of historians. Voltaire's "Charles the Twelfth," Marmontel's "Memoirs," Boswell's "Life of Johnson," Southey's account of Nelson, are perused with delight by the most frivolous and indolent. Whenever any tolerable book of the same description makes its appearance, the circulating libraries are mobbed; the book societies are in commotion; the new novel lies uncut; the magazines and newspapers fill their columns with extracts. In the mean time, histories of great empires, written by men of eminent ability, lie unread on the shelves of ostentatious libraries.

The writers of history seem to entertain an aristocratical contempt for the writers of memoirs. They think it beneath the dignity of men who describe the revolutions of nations to dwell on the details which constitute the charm of biography. They have imposed on themselves a code of conventional decencies as absurd as that which has been the bane of the French drama. The most characteristic and interesting circumstances are omitted or softened down because, as we are told, they are too trivial for the majesty of history. The majesty of history seems to resemble the majesty of the poor King of Spain who

[1] Reprinted from Macaulay's *Essay on History*.

died a martyr to ceremony because the proper dignitaries were not at hand to render him assistance.

That history would be more amusing if this etiquette were relaxed will, we suppose, be acknowledged. But would it be less dignified or less useful? What do we mean when we say that one past event is important and another insignificant? No past event has any intrinsic importance. The knowledge of it is valuable only as it leads us to form just calculations with respect to the future. A history which does not serve this purpose, though it may be filled with battles, treaties, and commotions, is as useless as the series of turnpike tickets collected by Sir Matthew Mite.

Let us suppose that Lord Clarendon, instead of filling hundreds of folio pages with copies of state papers, in which the same assertions and contradictions are repeated till the reader is overpowered with weariness, had condescended to be the Boswell of the Long Parliament. Let us suppose that he had exhibited to us the wise and lofty self-government of Hampden, leading while he seemed to follow, and propounding unanswerable arguments in the strongest forms with the modest air of an inquirer anxious for information; the delusions which misled the noble spirit of Vane; the coarse fanaticism which concealed the yet loftier genius of Cromwell, destined to control a mutinous army and a factious people, to abase the flag of Holland, to arrest the victorious arms of Sweden, and to hold the balance firm between the rival monarchies of France and Spain. Let us suppose that he had made his Cavaliers and Roundheads talk in their own style; that he had reported some of the ribaldry of Rupert's pages, and some of the cant of Harrison and Fleetwood. Would not his work in that case have been more interesting? Would it not have been more accurate?

A history in which every particular incident may be true may on the whole be false. The circumstances which have most influence on the happiness of mankind, the changes of manners and morals, the transition of communities from poverty to wealth, from knowledge to ignorance, from ferocity

to humanity—these are, for the most part, noiseless revolutions. Their progress is rarely indicated by what historians are pleased to call important events. They are not achieved by armies, or enacted by senates. They are sanctioned by no treaties, and recorded in no archives. They are carried on in every school, in every church, behind ten thousand counters, at ten thousand firesides. The upper current of society presents no certain criterion by which we can judge of the direction in which the under current flows. We read of defeats and victories; but we know that nations may be miserable amidst victories and prosperous amidst defeats. We read of the fall of wise ministers and of the rise of profligate favorites; but we must remember how small a proportion the good or evil affected by a single statesman can bear to the good or evil of a great social system.

Bishop Watson compares a geologist to a gnat mounted on an elephant, and laying down theories as to the whole internal structure of the vast animal, from the phenomena of the hide. The comparison is unjust to the geologists; but it is very applicable to those historians who write as if the body politic were homogeneous, who look only on the surface of affairs, and never think of the mighty and various organization which lies deep below.

In the works of such writers as these, England, at the close of the Seven Years' War, is in the highest state of prosperity; at the close of the American War she is in a miserable and degraded condition; as if the people were not on the whole as rich, as well governed, and as well educated at the latter period as at the former. We have read books called Histories of England, under the reign of George the Second, in which the rise of Methodism is not even mentioned. A hundred years hence this breed of authors will, we hope, be extinct. If it should still exist, the late ministerial interregnum will be described in terms which will seem to imply that all government was at an end; that the social contract was annulled; and that the hand of every man was against his neighbor, until the wisdom and virtue of the new Cabinet educed order out

of the chaos of anarchy.[1] We are quite certain that misconceptions as gross prevail at this moment respecting many important parts of our annals.

The effect of historical reading is analogous, in many respects, to that produced by foreign travel. The student, like the tourist, is transported into a new state of society. He sees new fashions. He hears new modes of expression. His mind is enlarged by contemplating the wide diversities of laws, of morals, and of manners. But men may travel far, and return with minds as contracted as if they had never stirred from their own market-town. In the same manner, men may know the dates of many battles and the genealogies of many royal houses, and yet be no wiser. Most people look at past times as princes look at foreign countries. More than one illustrious stranger has landed on our island amidst the shouts of a mob, has dined with the king, has hunted with the master of the stag-hounds; has seen the Guards reviewed, and a knight of the Garter installed; has cantered along Regent Street; has visited St. Paul's, and noted down its dimensions; and has then departed, thinking that he has seen England. He has, in fact, seen a few public buildings, public men, and public ceremonies. But of the vast and complex system of society, of the fine shades of national character, of the practical operation of government and laws, he knows nothing. He who would understand these things rightly must not confine his observations to palaces and solemn days. He must see ordinary men as they appear in their ordinary business and in their ordinary pleasures. He must mingle in the crowds of the exchange and the coffee-house. He must obtain admittance to the convivial table and the domestic hearth. He must bear with vulgar expressions. He must not shrink from exploring even the retreats of misery. He who wishes to understand the condition of mankind in former ages must proceed on the same principle. If he attends only to public transactions, to wars, congresses,

[1] At the end of 1827 and the beginning of 1828, political difficulties were such that the country was virtually left without responsible ministers during a period of six weeks.

and debates, his studies will be as unprofitable as the travels of those imperial, royal, and serene sovereigns who form their judgment of our island from having gone in state to a few fine sights, and from having held formal conferences with a few great officers.

The perfect historian is he in whose work the character and spirit of an age is exhibited in miniature. He relates no fact, he attributes no expression to his characters which is not authenticated by sufficient testimony. But, by judicious selection, rejection, and arrangement, he gives to truth those attractions which have been usurped by fiction. In his narrative a due subordination is observed: some transactions are prominent; others retire. But the scale on which he represents them is increased or diminished, not according to the dignity of the persons concerned in them, but according to the degree in which they elucidate the condition of society and the nature of man. He shows us the court, the camp, and the senate. But he shows us also the nation. He considers no anecdote, no peculiarity of manner, no familiar saying, as too insignificant for his notice which is not too insignificant to illustrate the operation of laws, of religion, and of education, and to mark the progress of the human mind. Men will not merely be described, but will be made intimately known to us. The changes of manners will be indicated, not merely by a few general phrases or a few extracts from statistical documents, but by appropriate images presented in every line.

If a man, such as we are supposing, should write the history of England, he would assuredly not omit the battles, the sieges, the negotiations, the seditions, the ministerial changes. But with these he would intersperse the details which are the charm of historical romances. At Lincoln Cathedral there is a beautiful painted window which was made by an apprentice out of the pieces of glass which had been rejected by his master. It is so far superior to every other in the church that, according to the tradition, the vanquished artist killed himself from mortification. Sir Walter Scott, in the same manner, has used those fragments of truth which historians have scornfully

thrown behind them in a manner which may well excite their envy. He has constructed out of their gleanings works which, even considered as histories, are scarcely less valuable than theirs. But a truly great historian would reclaim those materials which the novelist has appropriated. The history of the government and the history of the people would be exhibited in that mode in which alone they can be exhibited justly—in inseparable conjunction and intermixture. We should not then have to look for the wars and votes of the Puritans in Clarendon, and for their phraseology in "Old Mortality"; for one half of King James in Hume, and for the other half in "The Fortunes of Nigel."

The early part of our imaginary history would be rich with coloring from romance, ballad, and chronicle. We should find ourselves in the company of knights such as those of Froissart, and of pilgrims such as those who rode with Chaucer from the Tabard. Society would be shown from the highest to the lowest—from the royal cloth of state to the den of the outlaw; from the throne of the legate to the chimney-corner where the begging friar regaled himself. Palmers, minstrels, crusaders—the stately monastery, with the good cheer in its refectory and the high-mass in its chapel—the manor-house, with its hunting and hawking—the tournament, with the heralds and ladies, the trumpets and the cloth of gold—would give truth and life to the representation. We should perceive, in a thousand slight touches, the importance of the privileged burgher, and the fierce and haughty spirit which swelled under the collar of the degraded villain. The revival of letters would not merely be described in a few magnificent periods. We should discern, in innumerable particulars, the fermentation of mind, the eager appetite for knowledge, which distinguished the sixteenth from the fifteenth century. In the Reformation we should see, not merely a schism which changed the ecclesiastical constitution of England and the mutual relations of the European powers, but a moral war which raged in every family, which set the father against the son and the son against the father, the mother against the daughter and the

daughter against the mother. Henry would be painted with the skill of Tacitus. We should have the change of his character from his profuse and joyous youth to his savage and imperious old age. We should perceive the gradual progress of selfish and tyrannical passions in a mind not naturally insensible or ungenerous; and to the last we should detect some remains of that open and noble temper which endeared him to a people whom he oppressed, struggling with the hardness of despotism and the irritability of disease. We should see Elizabeth in all her weakness and in all her strength, surrounded by the handsome favorites whom she never trusted, and the wise old statesmen whom she never dismissed, uniting in herself the most contradictory qualities of both her parents—the coquetry, the caprice, the petty malice of Anne, the haughty and resolute spirit of Henry. We have no hesitation in saying that a great artist might produce a portrait of this remarkable woman at least as striking as that in the novel of "Kenilworth" without employing a single trait not authenticated by ample testimony. In the mean time, we should see arts cultivated, wealth accumulated, the conveniences of life improved. We should see the keeps, where nobles, insecure themselves, spread insecurity around them, gradually giving place to the halls of peaceful opulence, to the oriels of Longleat, and the stately pinnacles of Burleigh. We should see towns extended, deserts cultivated, the hamlets of fishermen turned into wealthy havens, the meal of the peasant improved, and his hut more commodiously furnished. We should see those opinions and feelings which produced the great struggle against the House of Stuart slowly growing up in the bosom of private families, before they manifested themselves in parliamentary debates. Then would come the civil war. Those skirmishes on which Clarendon dwells so minutely would be told, as Thucydides would have told them, with perspicuous conciseness. They are merely connecting links. But the great characteristics of the age—the loyal enthusiasm of the brave English gentry, the fierce licentiousness of the swearing, dicing, drunken reprobates whose excesses disgraced the royal cause—the austerity

of the Presbyterian Sabbaths in the city, the extravagance of the independent preachers in the camp, the precise garb, the severe countenance, the petty scruples, the affected accent, the absurd names and phrases which marked the Puritans—the valor, the policy, the public spirit, which lurked beneath these ungraceful disguises—the dreams of the raving Fifth-monarchy man, the dreams, scarcely less wild, of the philosophic republican—all these would enter into the representation, and render it at once more exact and more striking.

The instruction derived from history thus written would be of a vivid and practical character. It would be received by the imagination as well as by the reason. It would not be merely traced on the mind, but branded into it. Many truths, too, would be learned which can be learned in no other manner. As the history of states is generally written, the greatest and most momentous revolutions seem to come upon them like supernatural inflictions, without warning or cause. But the fact is, that such revolutions are almost always the consequences of moral changes, which have gradually passed on the mass of the community, and which ordinarily proceed far before their progress is indicated by any public measure. An intimate knowledge of the domestic history of nations is therefore absolutely necessary to the prognosis of political events. A narrative, defective in this respect, is as useless as a medical treatise which should pass by all the symptoms attendant on the early stage of a disease, and mention only what occurs when the patient is beyond the reach of remedies.

A historian such as we have been attempting to describe would indeed be an intellectual prodigy. In his mind, powers scarcely compatible with each other must be tempered into an exquisite harmony. We shall sooner see another Shakespeare or another Homer. The highest excellence to which any single faculty can be brought would be less surprising than such a happy and delicate combination of qualities. Yet the contemplation of imaginary models is not an unpleasant or useless employment of the mind. It can not indeed produce perfection; but it produces improvement, and nourishes

that generous and liberal fastidiousness which is not inconsistent with the strongest sensibility to merit, and which, while it exalts our conceptions of the art, does not render us unjust to the artist.

QUESTIONS AND EXERCISES

After one has learned to construct the whole composition as an organic unit and to build up the constituent parts into well-developed paragraphs, he is ready to consider making the sentences effective. In a writer's construction and use of sentences his real expertness is tested. "The sentence is the unit of style," says Professor Saintsbury, "and by the cadence and music, as well as by the purport and bearing of his sentences, the master of style must stand or fall." Stevenson implied that to the making of a good sentence there perhaps goes more intellectual effort and genuine skill than to the writing of an entire composition when he said: "From the arrangement of according letters, which is altogether arabesque and sensual up to the architecture of the elegant and pregnant sentence, which is a vigorous act of the pure intellect, there is scarce a faculty in man but has been exercised." If this be true, we are not surprised when he adds that perfect sentences are rare.

Success in sentence-making requires the endeavor to do three things: (1) to make the sentence clear in itself; (2) to make it strong in relation to its neighbors in the paragraph; and (3) to give variety of cadence to the series of sentences making up the paragraph. In the first of these, Macaulay had great success.

1. Freeman, the historian, has said: "I learned from Macaulay that if I wished to be understood by others, or indeed by myself, I must avoid not always long sentences—for long sentences may be perfectly clear—but involved, complicated, and parenthetical sentences. I learned that I must avoid sentences crowded with relatives and participles; sentences in which things were not so much directly stated as implied in some dark and puzzling fashion. . . . Macaulay never goes on, like some writers, talking about 'the former' and 'the latter,' 'he, she, it, they,' through clause after clause, while the reader has to look back to see which of several persons it is that is so darkly referred to. . . . With Macaulay's pronouns it is always perfectly clear who is meant by them." Do the sentences in this selection verify Freeman's statements about Macaulay's carefulness in regard to such matters as pronoun reference, placing of modifiers

near the words modified, avoidance of misrelated participles and squinting construction, etc.? Is the matter of syntactical correctness a matter of grammar or of rhetoric?

2. What is the average length of Macaulay's sentences? Examine the shortest sentences to see whether they are reserved for special uses, such as marking transitions, summarizing, or announcing ideas that are to be developed in succeeding sentences. Find several of the longer sentences and see if they are entirely clear. The shortness of Macaulay's sentences is valuable in keeping them from becoming crowded and confused in meaning, but is objectionable because it gives to his writing an air of abruptness and want of connection and prevents his securing effects of rhythm and melody. The habit of writing in short sentences shows, however, a tendency that is worthy of imitation by those who would write with clearness. The matter of sentence length cannot be regulated by absolute rules—a short sentence is not more intelligible than a carefully constructed long one—but it is not well to prolong any sentence so as to make it fatiguing to read or difficult to comprehend because the beginning is far from the end.

3. Several of Macaulay's paragraphs contain a succession of sentences beginning alike. Would more variety of beginnings be desirable? Are Macaulay's sentences usually loose or periodic? Point out some of the ways by which he makes his sentences periodic? A noticeable feature of Macaulay's sentences is parallelism; that is, the same form of statement and grammatical construction is kept for the parts that do the same work in the sentence. Point out sentences that show this characteristic.

4. In every sentence, some words carry more of the thought of the sentence than others. It is the business of the writer to make these words stand out so that the reader cannot miss them. This he does by seeing that the important words occupy the emphatic places at the beginning and the end of the sentence. Does Macaulay give his sentences emphasis? Discuss the periodic sentence as a type that is naturally emphatic.

Macaulay's success as a clear writer was due largely to his careful revision. According to his biographer, Trevelyan, it was his custom first to gather all the information needed for a particular piece of writing. Then he would sit down and write off the whole piece rapidly, "sketching in the outlines under the genial and audacious impulse of a first conception; and securing in black and white each idea, and epithet, and turn of phrase, as it flowed straight from his busy brain

to his rapid fingers. His manuscript, at this stage, to the eyes of anyone but himself, appeared to consist of column after column of dashes and flourishes, in which a straight line, with a half-formed letter at each end and another in the middle did duty for a word." As soon as the rough sketch of the whole had thus been made, Macaulay began to fill it in "at the rate of six sides of foolscap every morning; written in so large a hand, and with such a multitude of erasures, that the whole six pages were on the average compressed into two pages of print. . . . Macaulay never allowed a sentence to pass muster until it was as good as he could make it." When finally, after all this revision, he was satisfied that his writing was as good as he could make it, he submitted it to the criticism of others by reading it aloud to some of his family or friends. Macaulay's method of writing is suggestive of a distinction of great practical importance between the process by which a writer makes good paragraphs and whole compositions, and that by which he makes good sentences. He settles his paragraphs and whole compositions in advance by *planning;* he perfects his sentences through careful *revising*. During the writing of a composition it is hardly profitable to give much attention to the form of the sentences. The chief concern then should be to get the statements on paper in the proper order, letting the form in which they are put, for the time being, be of secondary importance. After the whole composition has thus been written in rough draft, should come the careful revision of sentences. Loose and disjointed forms of expression should be made terse and vigorous in statement The accidental compound sentences that are dashed off in the first draft should be turned into complex sentences that more properly express the relationship between ideas. The words of the sentence that are important for carrying on the thought should be made to stand out at the end of the sentence. All experience shows that in matters of sentence construction the way to improve is through conscientious revision.

Exercise 1. On one of the following subjects write a composition of about 500 words, paying little attention during composition to the kind of sentences used. When the first draft is finished, revise the sentences carefully. See that none of the sentences are left unduly long. Turn compound sentences into complex ones, unless there is clear need for the compound to express coördination or contrast of statements. Make the sentences mainly periodic.

Pirates.

Presence of mind.

The choice of a profession.
Your favorite periodical.
Great plagues and pestilences.
What makes a good letter.
Modern advertising methods.

Exercise 2. Revise an old composition for the same ends as those under Exercise 1.

RACIAL ELEMENTS OF ENGLISH CHARACTER[1]

MATTHEW ARNOLD

LET me repeat what I have often said of the characteristics which mark the English spirit, the English genius. This spirit, this genius, judged, to be sure, rather from a friend's than an enemy's point of view, yet judged on the whole fairly, is characterised, I have repeatedly said, by *energy with honesty*. Take away some of the energy which comes to us, as I believe, in part from Celtic and Roman sources; instead of energy, say rather *steadiness;* and you have the Germanic genius: *steadiness with honesty*. It is evident how nearly the two characterisations approach one another; and yet they leave, as we shall see, a great deal of room for difference. Steadiness with honesty; the danger for a national spirit thus composed is the humdrum, the plain and ugly, the ignoble; in a word *das Gemeine, die Gemeinheit*, that curse of Germany, against which Goethe was all his life fighting. The excellence of a national spirit thus composed is freedom from whim, flightiness, perverseness; patient fidelity to Nature,—in a word, *science*,—leading it at last, though slowly, and not by the most brilliant road, out of the bondage of the humdrum and common into the better life. The universal dead-level of plainness and homeliness, the lack of all beauty and distinction in form and feature, the slowness and clumsiness of the language, the eternal beer, sausages, and

[1] A portion of *On the Study of Celtic Literature*. Reprinted from the standard edition of Arnold's works, published by The Macmillan Company.

bad tobacco, the blank commonness everywhere, pressing at last like a weight on the spirits of the traveller in Northern Germany, and making him impatient to be gone,—this is the weak side; the industry, the well-doing, the patient, steady elaboration of things, the idea of science governing all departments of human activity,—this is the strong side; and through this side of her genius, Germany has already obtained excellent results, and is destined, we may depend upon it, however her pedantry, her slowness, her fumbling, her ineffectiveness, her bad government, may at times make us cry out, to an immense development.[1]

For dulness, the creeping Saxons,—says an old Irish poem, assigning the characteristics for which different nations are celebrated:—

> For acuteness and valour, the Greeks,
> For excessive pride, the Romans,
> For dulness, the creeping Saxons;
> For beauty and amorousness, the Gaedhils.

We have seen in what sense, and with what explanation, this characterization of the German may be allowed to stand; now let us come to the beautiful and amorous Gaedhil. Or rather, let us find a definition which may suit both branches of the Celtic family, the Cymri as well as the Gael. It is clear that special circumstances may have developed some one side in the national character of Cymri or Gael, Welshman or Irishman, so that the observer's notice shall be readily caught by this side, and yet it may be impossible to adopt it as characteristic of the Celtic nature generally. For instance, in his beautiful essay on the poetry of the Celtic races, M. Renan, with his eyes fixed on the Bretons and the Welsh, is struck with the timidity, the shyness, the delicacy of the Celtic nature, its preference for a retired life, its embarrassment at having to deal with the great world. He talks of the *douce petite race naturellement chrétienne*, his *race fière et timide, à l'extérieur gauche et embarrassée.* But it is evident that this description, however

[1] It is to be remembered that the above was written before the recent war between Prussia and Austria.—Arnold.

well it may do for the Cymri, will never do for the Gael, never do for the typical Irishman of Donnybrook fair. Again, M. Renan's *infinie délicatesse de sentiment qui caractérise la race Celtique*, how little that accords with the popular conception of an Irishman who wants to borrow money! *Sentiment* is, however, the word which marks where the Celtic races really touch and are one; sentimental, if the Celtic nature is to be characterised by a single term, is the best term to take. An organization quick to feel impressions, and feeling them very strongly; a lively personality therefore, keenly sensitive to joy and to sorrow; this is the main point. If the downs of life too much outnumber the ups, this temperament, just because it is so quickly and nearly conscious of all impressions, may no doubt be seen shy and wounded; it may be seen in wistful regret, it may be seen in passionate, penetrating melancholy; but its essence is to aspire ardently after life, light, and emotion, to be expansive, adventurous, and gay. Our word *gay*, it is said, is itself Celtic. It is not from *gaudium*, but from the Celtic *gair*, to laugh; and the impressionable Celt, soon up and soon down, is the more down because it is so his nature to be up—to be sociable, hospitable, eloquent, admired, figuring away brilliantly. He loves bright colours, he easily becomes audacious, overcrowing, full of fanfaronade. The German, say the physiologists, has the larger volume of intestines (and who that has ever seen a German at a table-d'hôte will not readily believe this?), the Frenchman has the more developed organs of respiration. That is just the expansive, eager Celtic nature; the head in the air, snuffing and snorting; *a proud look and a high stomach*, as the Psalmist says, but without any such settled savage temper as the Psalmist seems to impute by those words. For good and for bad, the Celtic genius is more airy and unsubstantial, goes less near the ground, than the German. The Celt is often called sensual; but it is not so much the vulgar satisfactions of sense that attract him as emotion and excitement; he is truly, as I began by saying, sentimental.

Sentimental,—*always ready to react against the despotism of fact;* that is the description a great friend of the Celt gives of

him; and it is not a bad description of the sentimental temperament; it lets us into the secret of its dangers and of its habitual want of success. Balance, measure, and patience, these are the eternal conditions, even supposing the happiest temperament to start with, of high success; and balance, measure, and patience are just what the Celt has never had. Even in the world of spiritual creation he has never, in spite of his admirable gifts of quick perception and warm emotion, succeeded perfectly, because he never has had steadiness, patience, sanity enough to comply with the conditions under which alone can expression be perfectly given to the finest perceptions and emotions. The Greek has the same perceptive, emotional temperament as the Celt; but he adds to this temperament the sense of *measure;* hence his admirable success in the plastic arts, in which the Celtic genius, with its chafing against the despotism of fact, its perpetual straining after mere emotion, has accomplished nothing. In the comparatively petty art of ornamentation, in rings, brooches, crosiers, relic-cases, and so on, he has done just enough to show his delicacy of taste, his happy temperament; but the grand difficulties of painting and sculpture, the prolonged dealings of spirit with matter, he has never had patience for. Take the more spiritual arts of music and poetry. All that emotion alone can do in music the Celt has done; the very soul of emotion breathes in the Scotch and Irish airs; but with all this power of musical feeling, what has the Celt, so eager for emotion that he has not patience for science, effected in music, to be compared with what the less emotional German, steadily developing his musical feeling with the science of a Sebastian Bach or a Beethoven, has effected? In poetry, again,—poetry which the Celt has so passionately, so nobly loved; poetry where emotion counts for so much, but where reason, too, reason, measure, sanity, also count for so much,—the Celt has shown genius, indeed, splendid genius; but even here his faults have clung to him, and hindered him from producing great works, such as other nations with a genius for poetry,—the Greeks, say, or the Italians,—have produced. The Celt has not produced great poetical works, he has only

produced poetry with an air of greatness investing it all, and sometimes giving, moreover, to short pieces, or to passages, lines, and snatches of long pieces, singular beauty and power. And yet he loved poetry so much that he grudged no pains to it; but the true art, the *architectonicê* which shapes great works, such as the *Agamemnon* or the *Divine Comedy*, comes only after a steady, deep-searching survey, a firm conception of the facts of human life, which the Celt has not patience for. So he runs off into technic, where he employs the utmost elaboration, and attains astonishing skill; but in the contents of his poetry you have only so much interpretation of the world as the first dash of a quick, strong perception, and then sentiment, infinite sentiment, can bring you. Here, too, his want of sanity and steadfastness has kept the Celt back from the highest success.

If his rebellion against fact has thus lamed the Celt even in spiritual work, how much more must it have lamed him in the world of business and politics! The skilful and resolute appliance of means to ends which is needed both to make progress in material civilisation and also to form powerful states, is just what the Celt has least turn for. He is sensual, as I have said, or at least sensuous; loves bright colours, company, and pleasure; and here he is like the Greek and Latin races; but compare the talent the Greek and Latin (or Latinized) races have shown for gratifying their senses, for procuring an outward life, rich, luxurious, splendid, with the Celt's failure to reach any material civilisation sound and satisfying, and not out at elbows, poor, slovenly, and half-barbarous. The sensuousness of the Greek made Sybaris and Corinth, the sensuousness of the Latin made Rome and Baiæ, the sensuousness of the Latinised Frenchman makes Paris; the sensuousness of the Celt proper has made Ireland. Even in his ideal heroic times, his gay and sensuous nature cannot carry him, in the appliances of his favourite life of sociability and pleasure, beyond the gross and creeping Saxon whom he despises; the regent Breas, we are told in the *Battle of Moytura of the Fomorians*, became unpopular because "the knives of his people were not greased at his table, nor did their breath smell of ale at the banquet."

In its grossness and barbarousness is not that Saxon, as Saxon as it can be? just what the Latinised Norman, sensuous and sociable like the Celt, but with the talent to make this bent of his serve to a practical embellishment of his mode of living, found so disgusting in the Saxon.

And as in material civilisation he has been ineffectual, so has the Celt been ineffectual in politics. This colossal, impetuous, adventurous wanderer, the Titan of the early world, who in primitive times fills so large a place on earth's scene, dwindles and dwindles as history goes on, and at last is shrunk to what we now see him. For ages and ages the world has been constantly slipping, ever more and more, out of the Celt's grasp. "They went forth to the war," Ossian says most truly, "*but they always fell.*"

And yet, if one sets about constituting an ideal genius, what a great deal of the Celt does one find oneself drawn to put into it! Of an ideal genius one does not want the elements, any of them, to be in a state of weakness; on the contrary, one wants all of them to be in the highest state of power; but with a law of measure, of harmony, presiding over the whole. So the sensibility of the Celt, if everything else were not sacrificed to it, is a beautiful and admirable force. For sensibility, the power of quick and strong perception and emotion, is one of the very prime constituents of genius, perhaps its most positive constituent; it is to the soul what good senses are to the body, the grand natural condition of successful activity. Sensibility gives genius its materials; one cannot have too much of it, if one can but keep its master and not be its slave. Do not let us wish that the Celt had had less sensibility, but that he had been more master of it. Even as it is, if his sensibility has been a source of weakness to him, it has been a source of power too, and a source of happiness. Some people have found in the Celtic nature and its sensibility the main root out of which chivalry and romance and the glorification of a feminine ideal spring; this is a great question, with which I cannot deal here. Let me notice in passing, however, that there is, in truth, a Celtic air about the extravagance of chivalry, its reaction

against the despotism of fact, its straining human nature further than it will stand. But putting all this question of chivalry and its origin on one side, no doubt the sensibility of the Celtic nature, its nervous exaltation, have something feminine in them, and the Celt is thus peculiarly disposed to feel the spell of the feminine idiosyncrasy; he has an affinity to it; he is not far from its secret. Again, his sensibility gives him a peculiarly near and intimate feeling of nature and the life of nature; here, too, he seems in a special way attracted by the secret before him, the secret of natural beauty and natural magic, and to be close to it, to half-divine it. In the productions of the Celtic genius, nothing, perhaps, is so interesting as the evidences of this power: I shall have occasion to give specimens of them by and by. The same sensibility made the Celts full of reverence and enthusiasm for genius, learning, and the things of the mind; *to be a bard, freed a man*,—that is a characteristic stroke of this generous and ennobling ardour of theirs, which no race has ever shown more strongly. Even the extravagance and exaggeration of the sentimental Celtic nature has often something romantic and attractive about it, something which has a sort of smack of misdirected good. The Celt, undisciplinable, anarchical, and turbulent by nature, but out of affection and admiration giving himself body and soul to some leader, that is not a promising political temperament, it is just the opposite of the Anglo-Saxon temperament, disciplinable and steadily obedient within certain limits, but retaining an inalienable part of freedom and self-dependence; but it is a temperament for which one has a kind of sympathy notwithstanding. And very often, for the gay defiant reaction against fact of the lively Celtic nature one has more than sympathy; one feels, in spite of the extravagance, in spite of good sense disapproving, magnetised and exhilarated by it. The Gauls had a rule inflicting a fine on every warrior who, when he appeared on parade, was found to stick out much in front,—to be corpulent, in short. Such a rule is surely the maddest article of war ever framed, and to people to whom nature has assigned a large volume of intestines, must appear, no doubt, horrible;

but yet has it not an audacious, sparkling, immaterial manner with it, which lifts one out of routine, and sets one's spirits in a glow?

All tendencies of human nature are in themselves vital and profitable; when they are blamed, they are only to be blamed relatively, not absolutely. This holds true of the Saxon's phlegm as well as of the Celt's sentiment. Out of the steady humdrum habit of the creeping Saxon, as the Celt calls him,—out of his way of going near the ground,—has come, no doubt, Philistinism, that plant of essentially Germanic growth, flourishing with its genuine marks only in the German fatherland, Great Britain and her colonies, and the United States of America; but what a soul of goodness there is in Philistinism itself! and this soul of goodness I, who am often supposed to be Philistinism's mortal enemy merely because I do not wish it to have things all its own way, cherish as much as anybody. This steady-going habit leads at last, as I have said, up to science, up to the comprehension and interpretation of the world. With us in Great Britain, it is true, it does not seem to lead so far as that; it is in Germany, where the habit is more unmixed, that it can lead to science. Here with us it seems at a certain point to meet with a conflicting force, which checks it and prevents its pushing on to science; but before reaching this point what conquests has it not won! and all the more, perhaps, for stopping short at this point, for spending its exertions within a bounded field, the field of plain sense, of direct practical utility. How it has augmented the comforts and conveniences of life for us! Doors that open, windows that shut, locks that turn, razors that shave, coats that wear, watches that go, and a thousand more such good things, are the invention of the Philistines.

Here, then, if commingling there is in our race, are two very unlike elements to commingle; the steady-going Saxon temperament and the sentimental Celtic temperament. But before we go on to try and verify, in our life and literature, the alleged fact of this commingling, we have yet another element to take into account, the Norman element. The critic in the *Saturday*

Review, whom I have already quoted, says that in looking for traces of Normanism in our national genius, as in looking for traces of Celtism in it, we do but lose our labour; he says, indeed, that there went to the original making of our nation a very great deal more of a Norman element than of a Celtic element, but he asserts that both elements have now so completely disappeared, that it is vain to look for any trace of either of them in the modern Englishman. But this sort of assertion I do not like to admit without trying it a little. I want, therefore, to get some plain notion of the Norman habit and genius, as I have sought to get some plain notion of the Saxon and Celtic. Some people will say that the Normans are Teutonic, and that therefore the distinguishing characters of the German genius must be those of their genius also; but the matter cannot be settled in this speedy fashion. No doubt the basis of the Norman race is Teutonic, but the governing point in the history of the Norman race,—so far, at least, as we English have to do with it,—is not its Teutonic origin, but its Latin civilisation. The French people have, as I have already remarked, an undoubtedly Celtic basis, yet so decisive in its effect upon a nation's habit and character can be the contact with a stronger civilisation, that Gaul, without changing the basis of her blood, became, for all practical intents and purposes, a Latin country, France and not Ireland, through the Roman conquest. Latinism conquered Celtism in her, as it also conquered the Germanism imported by the Frankish and other invasions; Celtism is, however, I need not say, everywhere manifest still in the French nation; even Germanism is distinctly traceable in it, as any one who attentively compares the French with other Latin races will see. No one can look carefully at the French troops in Rome, amongst the Italian population, and not perceive this trace of Germanism; I do not mean in the Alsatian soldiers only, but in the soldiers of genuine France. But the governing character of France, as a power in the world, is Latin; such was the force of Greek and Roman civilisation upon a race whose whole mass remained Celtic, and where the Celtic language still lingered on, they say, among the common people for some

five or six centuries after the Roman conquest. But the Normans in Neustria lost their old Teutonic language in a wonderfully short time; when they conquered England they were already Latinised; with them were a number of Frenchmen by race, men from Anjou and Poitou, so they brought into England more non-Teutonic blood, besides what they had themselves got by intermarriage, than is commonly supposed; the great point, however, is, that by civilisation this vigorous race, when it took possession of England, was Latin.

These Normans, who in Neustria had lost their old Teutonic tongue so rapidly, kept in England their new Latin tongue for some three centuries. It was Edward the Third's reign before English came to be used in law-pleadings and spoken at court. Why this difference? Both in Neustria and in England the Normans were a handful; but in Neustria, as Teutons, they were in contact with a more advanced civilisation than their own; in England, as Latins, with a less advanced. The Latinised Normans in England had the sense for fact, which the Celts had not; and the love of strenuousness, clearness, and rapidity, the high Latin spirit, which the Saxons had not. They hated the slowness and dulness of the creeping Saxon; it offended their clear, strenuous talent for affairs, as it offended the Celt's quick and delicate perception. The Normans had the Roman talent for affairs, the Roman decisiveness in emergencies. They have been called prosaic, but this is not a right word for them; they were neither sentimental, nor, strictly speaking, poetical. They had more sense for rhetoric than for poetry like the Romans; but, like the Romans, they had too high a spirit not to like a noble intellectual stimulus of some kind and thus they were carried out of the region of the merely prosaic. Their foible,—the bad excess of their characterising quality of strenuousness,—was not a prosaic flatness, it was hardness and insolence.

I have been obliged to fetch a very wide circuit, but at last I have got what I went to seek. I have got a rough, but, I hope, clear notion of these three forces, the Germanic genius, the Celtic genius, the Norman genius. The Germanic genius

has steadiness as its main basis, with commonness and humdrum for its defect, fidelity to nature for its excellence. The Celtic genius, sentiment as its main basis, with love of beauty, charm, and spirituality for its excellence, ineffectualness and self-will for its defect. The Norman genius, talent for affairs as its main basis, with strenuousness and clear rapidity for its excellence, hardness and insolence for its defect.

QUESTIONS AND EXERCISES

This selection illustrates more intricate devices of sentence construction than the selection from Macaulay. Arnold builds his sentences upon the idea that each should be such a unit of thought that (1) it can be grasped by itself, and (2) can be shown in its relation to the preceding and following ideas. As a general thing, he gives his sentences admirable emphasis.[1]

1. What is the average length of Arnold's sentences? Compare with Macaulay's.

2. From the sentences of paragraph 3 show that the form of sentence generally used by Arnold consists of two (or more) members, the first of which states the idea of the sentence in general terms; and the last of which makes the idea more specific and concrete. In other paragraphs find instances of this type of sentence. Point out some of its advantages. Besides this form of sentence, do you discover a wide variety of sentence forms? If so, do they exist merely for the sake of variety, or for clearness pure and simple? Does a large proportion of the sentences seem periodic, and is the effect of the style as a whole periodic? Do the sentences read smoothly?

3. Study Arnold's devices for throwing important words at the beginning or the end of the sentence. The gain in emphasis under Arnold's arrangement can be more readily appreciated if the statements of the sentence are thrown into their natural order by the student and then compared with Arnold's form. Note whether the end of each sentence serves to point the reader further on in the trend of the paragraph. Do the beginnings of his sentences seem chosen with reference to making a close connection with the preceding sentence?

4. Do Arnold's sentences impress you as being over-intricate?

[1] Here and elsewhere in these studies of Arnold's sentences I have followed Brewster's analysis in *Studies in Structure and Style*.

Do you have difficulty in grasping them? Do they suggest critical revision on the writer's part? How does Arnold's frequent repetition of a word assist sentence emphasis? Does suppression of connectives contribute to this quality of the sentences?

Exercise 1. Rewrite one of Arnold's paragraphs, breaking up his long sentences into shorter ones after the method of Macaulay. Show whether there has been any loss in exactness of statement. Point out whether there is any gain in terseness or trenchancy.

Exercise 2. Write 400–500-word compositions on one or more of the following subjects. Revise carefully for sentence structure. Endeavor to make moderately long sentences, but do not let this attempt lead to obscurity. Be careful of sentence emphasis.

The racial elements in the American of the future.

The elements of a successful lawyer (or some other profession).

The position of women in contemporary life.

The contributions of the Germanic race to history.

LITERATURE [1]

John Henry, Cardinal Newman

Here, then, in the first place, I observe, gentlemen, that literature from the derivation of the word implies writing, not speaking. This, however, arises from the circumstance of the copiousness, variety, and public circulation of the matters of which it consists. What is spoken cannot outrun the range of the speaker's voice, and perishes in the uttering. When words are in demand to express a long course of thought, when they have to be conveyed to the ends of the earth, or perpetuated for the benefit of posterity, they must be written down, that is, reduced to the shape of literature. Still, properly speaking, the terms by which we denote this characteristic gift of man belong to its exhibition by means of the voice, not of handwriting. It addresses itself, in its primary idea, to the ear, not to the eye. We call it the power of speech; we call it language, that

[1] Reprinted by permission from *The Idea of a University* (Longmans, Green, & Co.).

is, the use of the tongue; and even when we write we still keep in mind what was its original instrument, for we use freely such terms in our books as "saying," "speaking," "telling," "talking," "calling;" we use the terms "phraseology" and "diction," as if we were still addressing ourselves to the ear.

Now I insist on this because it shows that speech, and therefore literature, which is its permanent record, is essentially a personal work. It is not some production or result attained by the partnership of several persons, or by machinery, or by any natural process; but in its very idea it proceeds, and must proceed, from some one given individual. Two persons cannot be the authors of the sounds which strike our ear; and, as they cannot be speaking one and the same speech, neither can they be writing one and the same lecture or discourse,—which must certainly belong to some one person or other, and is the expression of that one person's ideas and feelings,—ideas and feelings personal to himself, though others may have parallel and similar ones,—proper to himself in the same sense as his voice, his air, his countenance, his carriage, and his action, are personal. In other words, literature expresses, not objective truth, as it is called, but subjective; not things, but thoughts.

Now this doctrine will become clearer by considering another use of words, which does relate to objective truth, or to things; which relates to matters not personal, not subjective to the individual, but which, even were there no individual man in the whole world to know them or to talk about them, would exist still. Such objects become the matter of science, and words indeed are used to express them; but such words are rather symbols than language, and however many we use, and however we may perpetuate them by writing, we never could make any kind of literature out of them, or call them by that name. Such, for instance, would be Euclid's Elements. They relate to truths universal and eternal; they are not mere thoughts, but things; they exist in themselves, not by virtue of our understanding them, not in dependence upon our will, but in what is called the *nature* of things, or at least on conditions external to us. The words, then, in which they are set forth are not

language, speech, literature, but rather, as I have said, symbols. And, as a proof of it, you will recollect that it is possible, nay usual, to set forth the propositions of Euclid in algebraical notation, which, as all would admit, has nothing to do with literature. What is true of mathematics is true also of every study, so far forth as it is scientific; it makes use of words as the mere vehicle of things, and is thereby withdrawn from the province of literature. Thus metaphysics, ethics, law, political economy, chemistry, theology, cease to be literature in the same degree as they are capable of a severe scientific treatment. And hence it is that Aristotle's works on the one hand, though at first sight literature, approach in character, at least a great number of them, to mere science; for even though the things which he treats of and exhibits may not always be real and true, yet he treats them as if they were, not as if they were the thoughts of his own mind; that is, he treats them scientifically. On the other hand, law or natural history has before now been treated by an author with so much of colouring derived from his own mind as to become a sort of literature. This is especially seen in the instance of theology, when it takes the shape of pulpit eloquence. It is seen too in historical composition, which becomes a mere specimen of chronology, or a chronicle, when divested of the philosophy, the skill, or the party and personal feelings of the particular writer. Science, then, has to do with things, literature with thoughts; science is universal, literature is personal; science uses words merely as symbols, but literature uses language in its full compass, as including phraseology, idiom, style, composition, rhythm, eloquence, and whatever other properties are included in it.

Let us then put aside the scientific use of words when we are to speak of language and literature. Literature is the personal use or exercise of language. That this is so is further proved from the fact that one author uses it so differently from another. Language itself in its very origination would seem to be traceable to individuals. Their peculiarities have given it its character. We are often able in fact to trace particular phrases or idioms to individuals; we know the history of their rise. Slang surely,

as it is called, comes of and breathes of the personal. The connection between the force of words in particular languages and the habits and sentiments of the nations speaking them has often been pointed out. And, while the many use language as they find it, the man of genius uses it indeed, but subjects it withal to his own purposes, and moulds it according to his own peculiarities. The throng and succession of ideas, thoughts, feelings, imaginations, aspirations, which pass within him, the abstractions, the juxtapositions, the comparisons, the discriminations, the conceptions, which are so original in him, his views of external things, his judgments upon life, manners, and history, the exercises of his wit, of his humour, of his depth, of his sagacity,—all these innumerable and incessant creations, the very pulsation and throbbing of his intellect, does he image forth, to all does he give utterance, in a corresponding language, which is as multiform as this inward mental action itself and analogous to it, the faithful expression of his intense personality, attending on his own inward world of thought as its very shadow; so that we might as well say that one man's shadow is another's as that the style of a really gifted mind can belong to any but himself. It follows him about *as* a shadow. His thought and feeling are personal, and so his language is personal.

Thought and speech are inseparable from each other; matter and expression are parts of one; style is a thinking out into language. This is what I have been laying down, and this is literature; not *things*, not the verbal symbols of things; not on the other hand mere *words*, but thoughts expressed in language. Call to mind, gentlemen, the meaning of the Greek word which expresses this special prerogative of man over the feeble intelligence of the inferior animals. It is called Logos. What does Logos mean? It stands both for *reason* and for *speech;* and it is difficult to say which it means more properly. It means both at once. Why? because really they cannot be divided,—because they are in a true sense one. When we can separate light and illumination, life and motion, the convex and the concave of a curve, then will it be possible for thought to tread speech under foot, and to hope to do without it—then

will it be conceivable that the vigorous and fertile intellect should renounce its own double, its instrument of expression, and the channel of its speculations and emotions.

Critics should consider this view of the subject before they lay down such canons of taste as the writer whose pages I have quoted. Such men as he is consider fine writing to be an *addition from without* to the matter treated of, a sort of ornament superinduced, or a luxury indulged in, by those who have time and inclination for such vanities. They speak as if *one* man could do the thought, and *another* the style. We read in Persian travels of the way in which young gentlemen go to work in the East when they would engage in correspondence with those who inspire them with hope or fear. They cannot write one sentence themselves; so they betake themselves to the professional letter-writer. They confide to him the object they have in view. They have a point to gain from a superior, a favour to ask, an evil to deprecate; they have to approach a man in power, or to make court to some beautiful lady. The professional man manufactures words for them as they are wanted, as a stationer sells them paper, or a schoolmaster might cut their pens. Thought and word are, in their conception, two things; and thus there is a division of labour. The man of thought comes to the man of words; and the man of words, duly instructed in the thought, dips the pen of desire into the ink of devotedness, and proceeds to spread it over the page of desolation. Then the nightingale of affection is heard to warble to the rose of loveliness, while the breeze of anxiety plays around the brow of expectation. This is what the Easterns are said to consider fine writing; and it seems pretty much the idea of the school of critics to whom I have been referring.

QUESTIONS AND EXERCISES

Upon a casual examination, Newman's sentences appear natural and easy, but upon closer analysis, they show great subtlety of construction and corresponding dexterity on the writer's part in handling difficult sentence forms.

1. Among the peculiarities of Newman's sentences is the frequent

parallelism. Clause is added to clause until a series of like constructions is piled up—words, phrases, or clauses. Find examples of this device. Does Newman show a tendency to omit connective in such sentences? What effect does this have on the movement of the sentences?

2. Are the parts of these sentences arranged so as to secure climax of idea? Are his sentences generally loose or periodic? Are they unpleasantly long at any time?

3. Does Newman seem to seek variety in sentences?

4. Note the cadence of Newman's sentences when read aloud. In the matter of cadence and rhythm it is necessary to give particular attention to the close of the sentence. Does Newman seem to prolong the close of his sentences in order to carry the rhythm to a full close, to fill out the cadence? Does he ever fall into the cadence of poetry?

Exercises. See exercises in sentence construction given on pages 96, 97, and 108.

CHOICE OF WORDS

AN APOLOGY FOR IDLERS[1]

ROBERT LOUIS STEVENSON

JUST now, when every one is bound, under pain of a decree in absence convicting them of *lèse*-respectability, to enter on some lucrative profession, and labor therein with something not far short of enthusiasm, a cry from the opposite party who are content when they have enough, and like to look on and enjoy in the meanwhile, savors a little of bravado and gasconade. And yet this should be. Idleness, so called, which does not consist in doing nothing, but in doing a great deal not recognized in the dogmatic formularies of the ruling class, has as good a right to state its position as industry itself. It is admitted that the presence of people who refuse to enter in the great handicap race for sixpenny pieces, is at once an insult and a disenchantment for those who do. A fine fellow (as we see so many) takes his determination, votes for the sixpences, and in the emphatic Americanism, "goes for" them. And while such an one is ploughing distressfully up the road, it is not hard to understand his resentment, when he perceives cool persons in the meadows by the wayside, lying with a handkerchief over their ears and a glass at their elbow. Alexander is touched in a very delicate place by the disregard of Diogenes. Where was the glory of having taken Rome for these tumultuous barbarians who poured into the Senate-house and found the Fathers sitting silent and unmoved by their success? It is a sore thing to have labored along and scaled the arduous hill-

[1] Reprinted from *Virginibus Puerisque* by permission of Messrs. Charles Scribner's Sons.

tops, and when all is done, find humanity indifferent to your achievement. Hence physicists condemn the unphysical; financiers have only a superficial toleration for those who know little of stocks; literary persons despise the unlettered; and people of all pursuits combine to disparage those who have none.

But though this is one difficulty of the subject, it is not the greatest. You could not be put in prison for speaking against industry, but you can be sent to Coventry for speaking like a fool. The greatest difficulty with most subjects is to do them well; therefore, please to remember this is an apology. It is certain that much may be judiciously argued in favor of diligence; only there is something to be said against it, and that is what, on the present occasion, I have to say. To state one argument is not necessarily to be deaf to all others, and that a man has written a book of travels in Montenegro is no reason why he should never have been to Richmond.

It is surely beyond a doubt that people should be a good deal idle in youth. For though here and there a Lord Macaulay may escape from school honors with all his wits about him, most boys pay so dear for their medals that they never afterwards have a shot in their locker, and begin the world bankrupt. And the same holds true during all the time a lad is educating himself, or suffers others to educate him. It must have been a very foolish old gentleman who addressed Johnson at Oxford in these words: "Young man, ply your book diligently now, and acquire a stock of knowledge; for when years come upon you, you will find that poring upon books will be but an irksome task." The old gentleman seems to have been unaware that many other things besides reading grow irksome, and not a few become impossible, by the time a man has to use spectacles and cannot walk without a stick. Books are good enough in their own way, but they are a mighty bloodless substitute for life. It seems a pity to sit, like the Lady of Shalott, peering into a mirror, with your back turned on all the bustle and glamour of reality. And if a man reads very hard, as the old anecdote reminds us, he will have little time for thought.

If you look back on your own education, I am sure it will not be the full, vivid, instructive hours of truantry that you regret; you would rather cancel some lack-lustre periods between sleep and waking in the class. For my own part, I have attended a good many lectures in my time. I still remember that the spinning of a top is a case of Kinetic Stability. I still remember that Emphyteusis is not a disease, nor Stillicide a crime. But though I would not willingly part with such scraps of science, I do not set the same store by them as by certain other odds and ends that I came by in the open street while I was playing truant. This is not the moment to dilate on that mighty place of education which was the favorite school of Dickens and of Balzac, and turns out yearly many inglorious masters in the Science of the Aspects of Life. Suffice it to say this: if a lad does not learn in the streets, it is because he has no faculty of learning. Nor is the truant always in the streets; for if he prefers, he may go out by the gardened suburbs into the country. He may pitch on some tuft of lilacs over a burn, and smoke innumerable pipes to the tune of the water on the stones. A bird will sing in the thicket. And there he may fall into a vein of kindly thought, and see things in a new perspective. Why, if this be not education, what is? We may conceive Mr. Worldly Wiseman accosting such an one, and the conversation that should thereupon ensue:

"How now, young fellow, what dost thou here?"

"Truly, sir, I take mine ease."

"Is not this the hour of the class? and should'st thou not be plying thy Book with diligence, to the end thou mayest obtain knowledge?"

"Nay, but thus also I follow after Learning, by your leave."

"Learning, quotha! After what fashion, I pray thee? Is it mathematics?"

"No, to be sure."

"Is it metaphysics?"

"Nor that."

"Is it some language?"

"Nay, it is no language."

"Is it a trade?"

"Nor a trade, neither."

"Why, then, what is't?"

"Indeed, sir, as a time may soon come for me to go upon Pilgrimage, I am desirous to note what is commonly done by persons in my case, and where are the ugliest Sloughs and Thickets on the Road; as also, what manner of Staff is of the best service. Moreover, I lie here, by this water, to learn by root-of-heart a lesson which my master teaches me to call Peace, or Contentment."

Hereupon Mr. Worldly Wiseman was much commoved with passion, and shaking his cane with a very threatful countenance, broke forth upon this wise: "Learning, quotha!" said he; "I would have all such rogues scourged by the Hangman!"

And so he would go his way, ruffling out his cravat with a crackle of starch, like a turkey when it spreads its feathers.

Now this, of Mr. Wiseman's, is the common opinion. A fact is not called a fact, but a piece of gossip, if it does not fall into one of your scholastic categories. An inquiry must be in some acknowledged direction, with a name to go by; or else you are not inquiring at all, only lounging; and the workhouse is too good for you. It is supposed that all knowledge is at the bottom of a well, or the far end of a telescope.

Sainte-Beuve, as he grew older, came to regard all experience as a single great book, in which to study for a few years ere we go hence; and it seemed all one to him whether you should read in Chapter xx., which is the differential calculus, or in Chapter xxxix., which is hearing the band play in the gardens. As a matter of fact, an intelligent person, looking out of his eyes and hearkening in his ears, with a smile on his face all the time, will get more true education than many another in a life of heroic vigils. There is certainly some chill and arid knowledge to be found upon the summits of formal and laborious science; but it is all round about you, and for the trouble of looking, that you will acquire the warm and palpitating facts of life. While others are filling their memory with a lumber of

words, one-half of which they will forget before the week be out, your truant may learn some really useful art: to play the fiddle, to know a good cigar, or to speak with ease and opportunity to all varieties of men. Many who have "plied their book diligently," and know all about some one branch or another of accepted lore, come out of the study with an ancient and owl-like demeanor, and prove dry, stockish, and dyspeptic in all the better and brighter parts of life. Many make a large fortune, who remain underbred and pathetically stupid to the last. And meantime there goes the idler, who began life along with them—by your leave, a different picture. He has had time to take care of his health and his spirits; he has been a great deal in the open air, which is the most salutary of all things for both body and mind; and if he has never read the great Book in very recondite places, he has dipped into it and skimmed it over to excellent purpose. Might not the student afford some Hebrew roots, and the business man some of his half-crowns, for a share of the idler's knowledge of life at large, and Art of Living? Nay, and the idler has another and more important quality than these. I mean his wisdom. He who has much looked on at the childish satisfaction of other people in their hobbies, will regard his own with only a very ironical indulgence. He will not be heard among the dogmatists. He will have a great and cool allowance for all sorts of people and opinions. If he finds no out-of-the-way truths, he will identify himself with no very burning falsehood. His way takes him along a by-road, not much frequented, but very even and pleasant, which is called Commonplace Lane, and leads to the Belvedere of Common Sense. Thence he shall command an agreeable, if no very noble prospect; and while others behold the East and West, the Devil and the Sunrise, he will be contentedly aware of a sort of morning hour upon all sublunary things, with an army of shadows running speedily and in many different directions into the great daylight of Eternity. The shadows and the generations, the shrill doctors and the plangent wars, go by into ultimate silence and emptiness; but underneath all this, a man may see, out of the Belvedere windows, much green

and peaceful landscape; many firelit parlors; good people laughing, drinking, and making love as they did before the Flood or the French Revolution; and the old shepherd telling his tale under the hawthorn.

Extreme *business*, whether at school or college, kirk or market, is a symptom of deficient vitality; and faculty for idleness implies a catholic appetite and a strong sense of personal identity. There is a sort of dead-alive, hackneyed people about, who are scarcely conscious of living except in the exercise of some conventional occupation. Bring these fellows into the country, or set them aboard ship, and you will see how they pine for their desk or their study. They have no curiosity; they cannot give themselves over to random provocations; they do not take pleasure in the exercise of their faculties for its own sake; and unless Necessity lays about them with a stick, they will even stand still. It is no good speaking to such folk: they *cannot* be idle, their nature is not generous enough; and they pass those hours in a sort of coma, which are not dedicated to furious moiling in the gold-mill. When they do not require to go to the office, when they are not hungry, and have no mind to drink, the whole breathing world is a blank to them. If they have to wait an hour or so for a train, they fall into a stupid trance with their eyes open. To see them, you would suppose there was nothing to look at and no one to speak with; you would imagine they were paralyzed or alienated; and yet very possibly they are hard workers in their own way, and have good eyesight for a flaw in a deed or a turn of the market. They have been to school and college, but all the time they had their eye on the medal; they have gone about in the world and mixed with clever people, but all the time they were thinking of their own affairs. As if a man's soul were not too small to begin with, they have dwarfed and narrowed theirs by a life of all work and no play; until here they are at forty, with a listless attention, a mind vacant of all material of amusement, and not one thought to rub against another, while they wait for the train. Before he was breeched he might have clambered on the boxes; when he was twenty, he would have stared at

the girls; but now the pipe is smoked out, the snuff-box empty, and my gentleman sits bolt upright upon a bench, with lamentable eyes. This does not appeal to me as being Success in Life.

But it is not only the person himself who suffers from his busy habits, but his wife and children, his friends and relations, and down to the very people he sits with in a railway carriage or an omnibus. Perpetual devotion to what a man calls his business is only to be sustained by perpetual neglect of many other things. And it is not by any means certain that a man's business is the most important thing he has to do. To an impartial estimate it will seem clear that many of the wisest, most virtuous, and most beneficent parts that are to be played upon the Theatre of Life are filled by gratuitous performers, and pass, among the world at large, as phases of idleness. For in that Theatre, not only the walking gentlemen, singing chambermaids, and diligent fiddlers in the orchestra, but those who look on and clap their hands from the benches, do really play a part and fulfill important offices towards the general result. You are no doubt very dependent on the care of your lawyer and stockbroker, of the guards and signalmen who convey you rapidly from place to place, and the policemen who walk the streets for your protection; but is there not a thought of gratitude in your heart for certain other benefactors who set you smiling when they fall in your way, or season your dinner with good company? Colonel Newcome helped to lose his friend's money; Fred Bayham had an ugly trick of borrowing shirts; and yet they were better people to fall among than Mr. Barnes. And though Falstaff was neither sober nor very honest, I think I could name one or two long-faced Barabbases whom the world could better have done without. Hazlitt mentions that he was more sensible of obligation to Northcote, who had never done him anything he could call a service, than to his whole circle of ostentatious friends; for he thought a good companion emphatically the greatest benefactor. I know there are people in the world who cannot feel grateful unless the favor has been done them at the cost of pain and difficulty. But this is a churlish disposition. A man may send you six sheets of letter-

paper covered with the most entertaining gossip, or you may pass half an hour pleasantly, perhaps profitably, over an article of his. Do you think the service would be greater, if he had made the manuscript in his heart's blood, like a compact with the devil? Do you really fancy you should be more beholden to your correspondent, if he had been damning you all the while for your importunity? Pleasures are more beneficial than duties because, like the quality of mercy, they are not strained, and they are twice blest. There must always be two to a kiss, and there may be a score in a jest; but wherever there is an element of sacrifice, the favor is conferred with pain, and, among generous people, received with confusion. There is no duty we so much underrate as the duty of being happy. By being happy, we sow anonymous benefits upon the world, which remain unknown even to ourselves, or, when they are disclosed, surprise nobody so much as the benefactor. The other day, a ragged, barefoot boy ran down the street after a marble, with so jolly an air that he set everyone he passed into a good humor; one of these persons, who had been delivered from more than usually black thoughts, stopped the little fellow and gave him some money with this remark: "You see what sometimes comes of looking pleased." If he had looked pleased before, he had now to look both pleased and mystified. For my part, I justify this encouragement of smiling rather than tearful children; I do not want to pay for tears anywhere but upon the stage; but I am prepared to deal largely in the opposite commodity. A happy man or woman is a better thing to find than a five-pound note. He or she is a radiating focus of goodwill; and their entrance into a room is as though another candle had been lighted. We need not care whether they could prove the forty-seventh proposition; they do a better thing than that, they practically demonstrate the great Theorem of the Liveableness of Life. Consequently, if a person cannot be happy without remaining idle, idle he should remain. It is a revolutionary precept; but, thanks to hunger and the workhouse, one not easily to be abused; and, within practical limits, it is one of the most incontestable truths in the whole

Body of Morality. Look at one of your industrious fellows for a moment, I beseech you. He sows hurry and reaps indigestion; he puts a vast deal of activity out to interest, and receives a large measure of nervous derangement in return. Either he absents himself entirely from all fellowship, and lives a recluse in a garret, with carpet slippers and a leaden inkpot; or he comes among people swiftly and bitterly, in a contraction of his whole nervous system, to discharge some temper before he returns to work. I do not care how much or how well he works, this fellow is an evil feature in other people's lives. They would be happier if he were dead. They could easier do without his services in the Circumlocution Office, than they can tolerate his fractious spirits. He poisons life at the well-head. It is better to be beggared out of hand by a scapegrace nephew, than daily hag-ridden by a peevish uncle.

And what, in God's name, is all this pother about? For what cause do they embitter their own and other people's lives? That a man should publish three or thirty articles a year, that he should finish or not finish his great allegorical picture, are questions of little interest to the world. The ranks of life are full; and although a thousand fall, there are always some to go into the breech. When they told Joan of Arc she should be at home minding women's work, she answered there were plenty to spin and wash. And so, even with your own rare gifts! When nature is "so careless of the single life," why should we coddle ourselves into the fancy that our own is of exceptional importance? Suppose Shakespeare had been knocked on the head some dark night in Sir Thomas Lucy's preserves, the world would have wagged no better or worse, the pitcher gone to the well, the scythe to the corn, and the student to his book; and no one been any the wiser of the loss. There are not many works extant, if you look the alternative all over, which are worth the price of a pound of tobacco to a man of limited means. This is a sobering reflection for the proudest of our earthly vanities. Even a tobacconist may, upon consideration, find no great cause for personal vainglory in the phrase; for although tobacco is an admirable sedative,

the qualities necessary for retailing it are neither rare nor precious in themselves. Alas and alas! you may take it how you will, but the services of no single individual are indispensable. Atlas was just a gentleman with a protracted nightmare! And yet you see merchants who go and labor themselves into a great fortune and thence into the bankruptcy court; scribblers who keep scribbling at little articles until their temper is a cross to all who come about them, as though Pharaoh should set the Israelites to make a pin instead of a pyramid; and fine young men who work themselves into a decline, and are driven off in a hearse with white plumes upon it. Would you not suppose these persons had been whispered, by the Master of the Ceremonies, the promise of some momentous destiny? and that this lukewarm bullet on which they play their farces was the bull's-eye and centre-point of all the universe? And yet it is not so. The ends for which they give away their priceless youth, for all they know, may be chimerical or hurtful; the glory and riches they expect may never come, or may find them indifferent; and they and the world they inhabit are so inconsiderable that the mind freezes at the thought.

QUESTIONS AND EXERCISES

From the title and the somewhat easy and humorous treatment, one is tempted to think this essay a mere bit of pleasantry. At bottom, however, there is a very vital philosophy which Stevenson is unobtrusively yet artfully and effectively making stimulating and attractive. Without formality, indeed with as much ease as is found to redeem many rambling essays, it progresses logically to its conclusion. It is, however, especially notable for its style. It shows how exposition may be at once logical in composition and literary in diction. The questions that follow direct attention to certain principles regarding the choice of words which may be noted in connection with it. Some questions for the further study of the sentence are also given.

1. What kind of vocabulary might one expect in this essay—an accurate and scientific one, or a suggestive and personal one?

2. Is Stevenson fond of comparatively unusual and unfamiliar words? Cite examples. Are all these words in good use? Whether

a word is in good use may be determined by asking (1) is it *reputable*—that is, in the language? (2) Is it *national*—that is, does it belong to the whole country? (3) Is it in use at the *present time?*

3. Make a careful examination of the words in several paragraphs and find the proportion of Saxon and Latin derivatives. Compare with paragraphs of other essays in this book, say *Americanism*. How would you characterize the difference in effect? Is Stevenson apt to choose the longer and more pompous word? Why?

4. Does Stevenson choose a word because it expresses his meaning plainly and accurately, or is he on the lookout for the word full of suggestiveness and attractiveness? Cite examples. Does he seem to avoid stereotyped words and phrases? Cite examples.

5. Is Stevenson's vocabulary distinctively a prose one, or do you note many words that lean towards poetic diction?

6. Does Stevenson select concrete words—words that call up images, or colorless, abstract words? Give examples.

7. How does Stevenson's average sentence compare in length with those of Macaulay and Newman? Are Stevenson's sentences harder to grasp than those of these other two writers? As the thought of this essay is somewhat loose and rambling, suggestiveness rather than accuracy being the evident aim, one might naturally expect the loose type of sentence to predominate over the periodic. Which type is the more common? Is Stevenson as fond of the balanced sentence as Newman and Macaulay? What would you say of the coherence of the sentences? Are they closely knit? Notice how many sentences begin with the word "and." What explanation would you make for the practice? Try the effect of omitting the "and."

8. What use does Stevenson make of the short sentence? Does he use it for summarizing? For emphasizing certain thoughts? See if the short sentences contain the most important thoughts of the paragraphs. Are they used merely for the sake of variety?

9. Stevenson's theory of sentence structure is expressed in the following paragraph, taken from his essay on *Style in Literature*. Are his own sentences good examples of this theory?

"The true business of the literary artist is to plait or weave his meaning, involving it around itself; so that each sentence by successive phrases, shall first come into a kind of knot, and then after a moment of suspended meaning, clear and solve itself. In every properly constructed sentence there should be observed this knot or hitch; so that (however delicately) we are led to foresee, to expect,

and then to welcome the successive phrases. The pleasure may be heightened by an element of surprise, as, very grossly, in the common figure of the antithesis, or, with much greater subtlety, where an antithesis is first suggested and then deftly evaded. Each phrase, besides, is to be comely in itself; and between the implication and the evolution of the sentence there should be a satisfying equipoise of sound; for nothing more often disappoints the ear than a sentence solemnly and sonorously prepared, and hastily and weakly finished. Nor should the balance be too striking and exact, for the one rule is to be infinitely various; to interest, to disappoint, to surprise, and yet still to gratify; to be ever changing, as it were, the stitch, and yet still to give the effect of an ingenious neatness."

Exercise 1. Upon one of the following topics write an informal essay after the style of Stevenson's.

An apology for hobbies.
An apology for absent-mindedness.
Building castles in the air.
Talking about one's health.
On being a grind.
Studying human nature.
Epitaphs.
On being a good fellow.
Superstitions.
A certain tendency of womankind on leaving a street-car.

Exercise 2. Write a denunciation of some social custom, for example, hand-shaking, introductions, party calls, etc.

THE VALUE OF EDUCATION IN SCIENCE[1]

John Stuart Mill

The most obvious part of scientific instruction—the mere information that it gives—speaks for itself. We are born into a world which we have not made; a world whose phenomena take place according to fixed laws, of which we do not bring

[1] A portion of the inaugural address delivered in 1867 before the University of St. Andrews, Scotland. Reprinted from *Discussions and Dissertations*, Vol. IV (Henry Holt & Co.).

any knowledge into the world with us. In such a world we are appointed to live, and in it all our work is to be done. Our whole working power depends on knowing the laws of the world —in other words, the properties of the things which we have to work with, and to work among, and to work upon. We may and do rely, for the greater part of this knowledge, on the few who in each department make its acquisition their main business in life. But unless an elementary knowledge of scientific truths is diffused among the public, they never know what is certain and what is not, or who are entitled to speak with authority and who are not: and they either have no faith at all in the testimony of science, or are the ready dupes of charlatans and impostors. They alternate between ignorant distrust and blind, often misplaced, confidence. Besides, who is there who would not wish to understand the meaning of the common physical facts that take place under his eye? Who would not wish to know why a pump raises water, why a lever moves heavy weights, why it is hot at the tropics and cold at the poles, why the moon is sometimes dark and sometimes bright, what is the cause of the tides? Do we not feel that he who is totally ignorant of these things, let him be ever so skilled in a special profession, is not an educated man, but an ignoramus? It is surely no small part of education to put us in intelligent possession of the most important and most universally interesting facts of the universe, so that the world which surrounds us may not be a sealed book to us, uninteresting because unintelligible. This, however, is but the simplest and most obvious part of the utility of science, and the part which, if neglected in youth, may be the most easily made up for afterwards. It is more important to understand the value of scientific instruction as a training and disciplining process, to fit the intellect for the proper work of a human being. Facts are the materials of our knowledge, but the mind itself is the instrument; and it is easier to acquire facts, than to judge what they prove, and how, through the facts which we know, to get to those which we want to know.

The most incessant occupation of the human intellect through-

out life is the ascertainment of truth. We are always needing to know what is actually true about something or other. It is not given to us all to discover great general truths that are a light to all men and to future generations; though with a better general education the number of those who could do so would be far greater than it is. But we all require the ability to judge between the conflicting opinions which are offered to us as vital truths; to choose what doctrines we will receive in the matter of religion, for example; to judge whether we ought to be Tories, Whigs, or Radicals, or to what length it is our duty to go with each; to form a rational conviction on great questions of legislation and internal policy, and on the manner in which our country should behave to dependencies and to foreign nations. And the need we have of knowing how to discriminate truth, is not confined to the larger truths. All through life it is our most pressing interest to find out the truth about all the matters we are concerned with. If we are farmers we want to find what will truly improve our soil; if merchants, what will truly influence the markets of our commodities; if judges, or jurymen, or advocates, who it was that truly did an unlawful act, or to whom a disputed right truly belongs. Every time we have to make a new resolution or alter an old one, in any situation in life, we shall go wrong unless we know the truth about the facts on which our resolution depends. Now, however different these searches for truth may look, and however unlike they really are in their subject-matter, the methods of getting at truth, and the tests of truth, are in all cases much the same. There are but two roads by which truth can be discovered—observation and reasoning; observation, of course, including experiment. We all observe, and we all reason, and therefore, more or less successfully, we all ascertain truths; but most of us do it very ill, and could not get on at all were we not able to fall back on others who do it better. If we could not do it in any degree, we should be mere instruments in the hands of those who could: they would be able to reduce us to slavery. Then how shall we best learn to do this? By being shown the way in which it has already been successfully

done. The processes by which truth is attained, reasoning and observation, have been carried to their greatest known perfection in the physical sciences. As classical literature furnishes the most perfect types of the art of expression, so do the physical sciences those of the art of thinking. Mathematics, and its application to astronomy and natural philosophy, are the most complete example of the discovery of truths by reasoning; experimental science, of their discovery by direct observation. In all these cases we know that we can trust the operation, because the conclusions to which it has led have been found true by subsequent trial. It is by the study of these, then, that we may hope to qualify ourselves for distinguishing truth, in cases where there do not exist the same ready means of verification.

In what consists the principal and most characteristic difference between one human intellect and another? In their ability to judge correctly of evidence. Our direct perceptions of truth are so limited,—we know so few things by immediate intuition, or, as it used to be called, by simple apprehension,—that we depend, for almost all our valuable knowledge, on evidence external to itself; and most of us are very unsafe hands at estimating evidence, where an appeal cannot be made to actual eyesight. The intellectual part of our education has nothing more important to do than to correct or mitigate this almost universal infirmity—this summary and substance of nearly all purely intellectual weakness. To do this with effect needs all the resources which the most perfect system of intellectual training can command. Those resources, as every teacher knows, are but of three kinds: first, models; secondly, rules; thirdly, appropriate practice. The models of the art of estimating evidence are furnished by science; the rules are suggested by science; and the study of science is the most fundamental portion of the practice.

Take, in the first instance, mathematics. It is chiefly from mathematics we realize the fact that there actually is a road to truth by means of reasoning; that anything real, and which will be found true when tried, can be arrived at by a mere

operation of the mind. The flagrant abuse of mere reasoning in the days of the schoolmen, when men argued confidently to supposed facts of outward nature without properly establishing their premises, or checking the conclusions by observation, created a prejudice in the modern, and especially in the English mind, against deductive reasoning altogether, as a mode of investigation. The prejudice lasted long, and was upheld by the misunderstood authority of Lord Bacon; until the prodigious applications of mathematics to physical science—to the discovery of the laws of external nature—slowly and tardily restored the reasoning process to the place which belongs to it as a source of real knowledge. Mathematics, pure and applied, are still the great conclusive example of what can be done by reasoning. Mathematics also habituates us to several of the principal precautions for the safety of the process. Our first studies in geometry teach us two invaluable lessons. One is, to lay down at the beginning, in express and clear terms, all the premises from which we intend to reason. The other is, to keep every step in the reasoning distinct and separate from all the other steps, and to make each step safe before proceeding to another; expressly stating to ourselves, at every joint in the reasoning, what new premise we there introduce. It is not necessary that we should do this at all times, in all our reasonings. But we must be always able and ready to do it. If the validity of our argument is denied, or if we doubt it ourselves, that is the way to check it. In this way we are often enabled to detect at once the exact place where paralogism or confusion get in: and after sufficient practice we may be able to keep them out from the beginning. It is to mathematics, again, that we owe our first notion of a connected body of truth; truths which grow out of one another, and hang together so that each implies all the rest; that no one of them can be questioned without contradicting another or others, until in the end it appears that no part of the system can be false unless the whole is so. Pure mathematics first gave us this conception; applied mathematics extends it to the realm of physical nature. Applied mathematics shows us that not only the truths of

abstract number and extension, but the external facts of the universe, which we apprehend by our senses, form, at least in a large part of all nature, a web similarly held together. We are able, by reasoning from a few fundamental truths, to explain and predict the phenomena of material objects: and what is still more remarkable, the fundamental truths were themselves found out by reasoning; for they are not such as are obvious to the senses, but had to be inferred by a mathematical process from a mass of minute details, which alone came within the direct reach of human observation. When Newton, in this manner, discovered the laws of the solar system, he created, for all posterity, the true idea of science. He gave the most perfect example we are ever likely to have, of that union of reasoning and observation, which by means of facts that can be directly observed, ascends to laws which govern multitudes of other facts—laws which not only explain and account for what we see, but give us assurance beforehand of much that we do not see, much that we never could have found out by observation, though, having been found out, it is always verified by the result.

While mathematics, and the mathematical sciences, supply us with a typical example of the ascertainment of truth by reasoning,—those physical sciences which are not mathematical, such as chemistry, and purely experimental physics, show us in equal perfection the other mode of arriving at certain truth, by observation, in its most accurate form—that of experiment. The value of mathematics in a logical point of view is an old topic with mathematicians, and has even been insisted on so exclusively as to provoke a counter-exaggeration, of which a well-known essay by Sir William Hamilton is an example: but the logical value of experimental science is comparatively a new subject; yet there is no intellectual discipline more important than that which the experimental sciences afford. Their whole occupation consists in doing well, what all of us, during the whole of life, are engaged in doing, for the most part badly. All men do not affect to be reasoners, but all profess, and really attempt, to draw inferences from experience: yet

hardly any one, who has not been a student of the physical sciences, sets out with any just idea of what the process of interpreting experience really is. If a fact has occurred once or oftener, and another fact has followed it, people think they have got an experiment, and are well on the road towards showing that the one fact is the cause of the other. If they did but know the immense amount of precaution necessary to a scientific experiment; with what sedulous care the accompanying circumstances are contrived and varied, so as to exclude every agency but that which is the subject of the experiment—or, when disturbing agencies cannot be excluded, the minute accuracy with which their influence is calculated and allowed for, in order that the residue may contain nothing but what is due to the one agency under examination; if these things were attended to, people would be much less easily satisfied that their opinions have the evidence of experience; many popular notions and generalizations which are in all mouths, would be thought a great deal less certain than they are supposed to be; but we should begin to lay the foundation of really experimental knowledge on things which are now the subjects of mere vague discussion, where one side finds as much to say and says it as confidently as another, and each person's opinion is less determined by evidence than by his accidental interest or prepossession. In politics, for instance, it is evident to whoever comes to the study from that of the experimental sciences, that no political conclusions of any value for practice can be arrived at by direct experience. Such specific experience as we can have serves only to verify, and even that insufficiently, the conclusions of reasoning. Take any active force you please in politics; take the liberties of England, or free trade; how should we know that either of these things conduced to prosperity, if we could discern no tendency in the things themselves to produce it? If we had only the evidence of what is called our experience, such prosperity as we enjoy might be owing to a hundred other causes, and might have been obstructed, not promoted, by these. All true political science is, in one sense of the phrase, *a priori*, being deduced from the tendencies of things—tendencies known

either through our general experience of human nature, or as the result of an analysis of the course of history, considered as a progressive evolution. It requires, therefore, the union of induction and deduction, and the mind that is equal to it must have been well disciplined in both. But familiarity with scientific experiment at least does the useful service of inspiring a wholesome scepticism about the conclusions which the mere surface of experience suggests.

The study, on the one hand, of mathematics and its applications, on the other, of experimental science, prepares us for the principal business of the intellect, by the practice of it in the most characteristic cases, and by familiarity with the most perfect and successful models of it. But in great things as in small, examples and models are not sufficient: we want rules as well. Familiarity with the correct use of a language in conversation and writing does not make rules of grammar unnecessary; nor does the amplest knowledge of sciences of reasoning and experiment dispense with rules of logic. We may have heard correct reasonings and seen skilful experiments all our lives—we shall not learn by mere imitation to do the like, unless we pay careful attention to how it is done. It is much easier in these abstract matters, than in purely mechanical ones, to mistake bad work for good. To mark out the difference between them is the province of logic. Logic lays down the general principles and laws of the search after truth; the conditions which, whether recognized or not, must actually have been observed if the mind has done its work rightly. Logic is the intellectual complement of mathematics and physics. Those sciences give the practice, of which Logic is the theory. It declares the principles, rules, and precepts, of which they exemplify the observance.

The science of Logic has two parts: ratiocinative and inductive logic. The one helps to keep us right in reasoning from premises, the other in concluding from observation. Ratiocinative logic is much older than inductive, because reasoning in the narrower sense of the word is an easier process than induction, and the science which works by mere reasoning, pure

mathematics, had been carried to a considerable height while the sciences of observation were still in the purely empirical period. The principles of ratiocination, therefore, were the earliest understood and systematized, and the logic of ratiocination is even now suitable to an earlier stage in education than that of induction. The principles of induction cannot be properly understood without some previous study of the inductive sciences; but the logic of reasoning, which was already carried to a high degree of perfection by Aristotle, does not absolutely require even a knowledge of mathematics, but can be sufficiently exemplified and illustrated from the practice of daily life.

Of Logic I venture to say, even if limited to that of mere ratiocination, the theory of names, propositions, and the syllogism, that there is no part of intellectual education which is of greater value, or whose place can so ill be supplied by anything else. Its uses, it is true, are chiefly negative; its function is, not so much to teach us to go right, as to keep us from going wrong. But in the operations of the intellect it is so much easier to go wrong than right; it is so utterly impossible for even the most vigorous mind to keep itself in the path but by maintaining a vigilant watch against all deviations, and noting all the byways by which it is possible to go astray—that the chief difference between one reasoner and another consists in their less or greater liability to be misled. Logic points out all the possible ways in which, starting from true premises, we may draw false conclusions. By its analysis of the reasoning process, and the forms it supplies for stating and setting forth our reasonings, it enables us to guard the points at which a fallacy is in danger of slipping in, or to lay our fingers upon the place where it has slipped in. When I consider how very simple the theory of reasoning is, and how short a time is sufficient for acquiring a thorough knowledge of its principles and rules, and even considerable expertness in applying them, I can find no excuse for omission to study it on the part of any one who aspires to succeed in any intellectual pursuit. Logic is the great disperser of hazy and confused thinking: it clears up the fogs

which hide from us our own ignorance, and make us believe that we understand a subject when we do not. We must not be led away by talk about inarticulate giants who do great deeds without knowing how, and see into the most recondite truths without any of the ordinary helps, and without being able to explain to other people how they reach their conclusions, nor consequently to convince any other people of the truth of them. There may be such men, as there are deaf and dumb persons who do clever things; but for all that, speech and hearing are faculties by no means to be dispensed with. If you want to know whether you are thinking rightly, put your thoughts into words. In the very attempt to do this you will find yourselves, consciously or unconsciously, using logical forms. Logic compels us to throw our meaning into distinct propositions, and our reasonings into distinct steps. It makes us conscious of all the implied assumptions on which we are proceeding, and which, if not true, vitiate the entire process. It makes us aware what extent of doctrine we commit ourselves to by any course of reasoning, and obliges us to look the implied premises in the face, and make up our minds whether we can stand to them. It makes our opinions consistent with themselves and with one another, and forces us to think clearly, even when it cannot make us think correctly. It is true that error may be consistent and systematic as well as truth; but this is not the common case. It is no small advantage to see clearly the principles and consequences involved in our opinions, and which we must either accept, or else abandon those opinions. We are much nearer to finding truth when we search for it in broad daylight. Error, pursued rigorously to all that is implied in it, seldom fails to get detected by coming into collision with some known and admitted fact.

You will find abundance of people to tell you that logic is no help to thought, and that people cannot be taught to think by rules. Undoubtedly rules by themselves, without practice, go but a little way in teaching anything. But if the practice of thinking is not improved by rules, I venture to say it is the only difficult thing done by human beings that is not so.

A man learns to saw wood principally by practice, but there are rules for doing it, grounded on the nature of the operation, and if he is not taught the rules, he will not saw well until he has discovered them for himself. Wherever there is a right way and a wrong, there must be a difference between them, and it must be possible to find out what the difference is; and when found out and expressed in words, it is a rule for the operation. If any one is inclined to disparage rules, I say to him, try to learn anything which there are rules for, without knowing the rules, and see how you succeed. To those who think lightly of the school logic, I say, take the trouble to learn it. You will easily do so in a few weeks, and you will see whether it is of no use to you in making your mind clear, and keeping you from stumbling in the dark over the most outrageous fallacies. Nobody, I believe, who has really learned it, and who goes on using his mind, is insensible to its benefits, unless he started with a prejudice, or, like some eminent English and Scottish thinkers of the past century, is under the influence of a reaction against the exaggerated pretensions made by the schoolmen, not so much in behalf of logic as of the reasoning process itself. Still more highly must the use of logic be estimated, if we include in it, as we ought to do, the principles and rules of Induction as well as of Ratiocination. As the one logic guards us against bad deduction, so does the other against bad generalization, which is a still more universal error. If men easily err in arguing from one general proposition to another, still more easily do they go wrong in interpreting the observations made by themselves and others. There is nothing in which an untrained mind shows itself more hopelessly incapable, than in drawing the proper general conclusions from its own experience. And even trained minds, when all their training is on a special subject, and does not extend to the general principles of induction, are only kept right when there are ready opportunities of verifying their inferences by facts. Able scientific men, when they venture upon subjects in which they have no facts to check them, are often found drawing conclusions or making generalizations from their experimental

knowledge, such as any sound theory of induction would show to be utterly unwarranted. So true is it that practice alone, even of a good kind, is not sufficient without principles and rules. Lord Bacon had the great merit of seeing that rules were necessary, and conceiving, to a very considerable extent, their true character. The defects of his conception were such as were inevitable while the inductive sciences were only in the earliest stage of their progress, and the highest efforts of the human mind in that direction had not yet been made. Inadequate as the Baconian view of induction was, and rapidly as the practice outgrew it, it is only within a generation or two that any considerable improvement has been made in the theory; very much through the impulse given by two of the many distinguished men who have adorned the Scottish universities—Dugald Stewart and Brown.

I have given a very incomplete and summary view of the educational benefits derived from instruction in the more perfect sciences, and in the rules for the proper use of the intellectual faculties which the practice of those sciences has suggested. There are other sciences, which are in a more backward state, and tax the whole powers of the mind in its mature years, yet a beginning of which may be beneficially made in university studies, while a tincture of them is valuable even to those who are never likely to proceed farther. The first is physiology; the science of the laws of organic and animal life, and especially of the structure and functions of the human body. It would be absurd to pretend that a profound knowledge of this difficult subject can be acquired in youth, or as a part of general education. Yet an acquaintance with its leading truths is one of those acquirements which ought not to be the exclusive property of a particular profession. The value of such knowledge for daily uses has been made familiar to us all by the sanitary discussions of late years. There is hardly one among us who may not, in some position of authority, be required to form an opinion and take part in public action on sanitary subjects. And the importance of understanding the true conditions of health and disease—of knowing how to acquire and preserve

that healthy habit of body which the most tedious and costly medical treatment so often fails to restore when once lost—should secure a place in general education for the principal maxims of hygiene, and some of those even of practical medicine. For those who aim at high intellectual cultivation, the study of physiology has still greater recommendations, and is, in the present state of advancement of the higher studies, a real necessity. The practice which it gives in the study of nature is such as no other physical science affords in the same kind, and is the best introduction to the difficult questions of politics and social life. Scientific education, apart from professional objects, is but a preparation for judging rightly of Man, and of his requirements and interests. But to this final pursuit, which has been called *par excellence* the proper study of mankind, physiology is the most serviceable of the sciences, because it is the nearest. Its subject is already Man: the same complex and manifold being, whose properties are not independent of circumstance, and immovable from age to age, like those of the ellipse and hyperbola, or of sulphur and phosphorus, but are infinitely various, indefinitely modifiable by art or accident, graduating by the nicest shades into one another, and reacting upon one another in a thousand ways, so that they are seldom capable of being isolated and observed separately. With the difficulties of the study of a being so constituted, the physiologist, and he alone among scientific inquirers, is already familiar. Take what view we will of man as a spiritual being, one part of his nature is far more like another than either of them is like anything else. In the organic world we study nature under disadvantages very similar to those which affect the study of moral and political phenomena: our means of making experiments are almost as limited, while the extreme complexity of the facts makes the conclusions of general reasoning unusually precarious, on account of the vast number of circumstances that conspire to determine every result. Yet, in spite of these obstacles, it is found possible in physiology to arrive at a considerable number of well-ascertained and important truths. This, therefore, is an excellent school in which to study the

means of overcoming similar difficulties elsewhere. It is in physiology, too, that we are first introduced to some of the conceptions which play the greatest part in the moral and social sciences, but which do not occur at all in those of inorganic nature; as, for instance, the idea of predisposition, and of predisposing causes, as distinguished from exciting causes. The operation of all moral forces is immensely influenced by predisposition: without that element, it is impossible to explain the commonest facts of history and social life. Physiology is also the first science in which we recognize the influence of habit—the tendency of something to happen again merely because it has happened before. From physiology, too, we get our clearest notion of what is meant by development or evolution. The growth of a plant or animal from the first germ is the typical specimen of a phenomenon which rules through the whole course of the history of man and society—increase of function, through expansion and differentiation of structure by internal forces. I cannot enter into the subject at greater length; it is enough if I throw out hints which may be germs of further thought in yourselves. Those who aim at high intellectual achievements may be assured that no part of their time will be less wasted, than that which they employ in becoming familiar with the methods and with the main conceptions of the science of organization and life.

Physiology, at its upper extremity, touches on Psychology, or the Philosophy of Mind: and without raising any disputed questions about the limits between Matter and Spirit, the nerves and brain are admitted to have so intimate a connection with the mental operations, that the student of the last cannot dispense with a considerable knowledge of the first. The value of psychology itself need hardly be expatiated upon in a Scottish university; for it has always been there studied with brilliant success. Almost everything which has been contributed from these islands towards its advancement since Locke and Berkeley, has until very lately, and much of it even in the present generation, proceeded from Scottish authors and Scottish professors. Psychology, in truth, is simply the knowledge of the

laws of human nature. If there is anything that deserves to be studied by man, it is his own nature and that of his fellow-men: and if it is worth studying at all, it is worth studying scientifically, so as to reach the fundamental laws which underlie and govern all the rest. With regard to the suitableness of this subject for general education, a distinction must be made. There are certain observed laws of our thoughts and of our feelings which rest upon experimental evidence, and, once seized, are a clew to the interpretation of much that we are conscious of in ourselves, and observe in one another. Such, for example, are the laws of association. Psychology, so far as it consists of such laws,—I speak of the laws themselves, not of their disputed applications,—is as positive and certain a science as chemistry, and fit to be taught as such. When, however, we pass beyond the bounds of these admitted truths, to questions which are still in controversy among the different philosophical schools—how far the higher operations of the mind can be explained by association, how far we must admit other primary principles—what faculties of the mind are simple, what complex, and what is the composition of the latter—above all, when we embark upon the sea of metaphysics properly so called, and inquire, for instance, whether time and space are real existences, as is our spontaneous impression, or forms of our sensitive faculty, as is maintained by Kant, or complex ideas generated by association; whether matter and spirit are conceptions merely relative to our faculties, or facts existing *per se*, and in the latter case, what is the nature and limit of our knowledge of them; whether the will of man is free or determined by causes, and what is the real difference between the two doctrines; matters on which the most thinking men, and those who have given most study to the subjects, are still divided; it is neither to be expected nor desired that those who do not specially devote themselves to the higher departments of speculation should employ much of their time in attempting to get to the bottom of these questions. But it is a part of liberal education to know that such controversies exist, and, in a general way, what has been said on both sides of them.

It is instructive to know the failures of the human intellect as well as its successes, its imperfect as well as its perfect attainments; to be aware of the open questions, as well as of those which have been definitively resolved. A very summary view of these disputed matters may suffice for the many; but a system of education is not intended solely for the many; it has to kindle the aspirations and aid the efforts of those who are destined to stand forth as thinkers above the multitude: and for these there is hardly to be found any discipline comparable to that which these metaphysical controversies afford. For they are essentially questions about the estimation of evidence; about the ultimate grounds of belief; the conditions required to justify our most familiar and intimate convictions; and the real meaning and import of words and phrases which we have used from infancy as if we understood all about them, which are even at the foundation of human language, yet of which no one except a metaphysician has rendered to himself a complete account. Whatever philosophical opinions the study of these questions may lead us to adopt, no one ever came out of the discussion of them without increased vigor of understanding, an increased demand for precision of thought and language, and a more careful and exact appreciation of the nature of proof. There never was any sharpener of the intellectual faculties superior to the Berkeleian controversy. There is even now no reading more profitable to students—confining myself to writers in our own language, and notwithstanding that so many of their speculations are already obsolete—than Hobbes and Locke, Reid and Stewart, Hume, Hartley, and Brown; on condition that these great thinkers are not read passively, as masters to be followed, but actively, as supplying materials and incentives to thought. To come to our own contemporaries, he who has mastered Sir William Hamilton and your own lamented Ferrier as distinguished representatives of one of the two great schools of philosophy, and an eminent Professor in a neighboring University, Professor Bain, probably the greatest living authority in the other, has gained a practice in the most searching methods of philosophic investigation

applied to the most arduous subjects, which is no inadequate preparation for any intellectual difficulties that he is ever likely to be called on to resolve.

QUESTIONS AND EXERCISES

This selection from Mill exemplifies a style which, in contrast with that of Stevenson, uses learned and philosophical terms freely and evidently seeks exactness and discrimination in the use of words. It is typical of the object the scientific writer holds before himself in the selection of words, namely, precision.

1. Express, in your own words, the difference in general impression that the diction of the selection from Mill makes in comparison with that from Stevenson. Which seems to be the determining factor in the choice of word by Mill—its suggestiveness (connotation) or its literal meaning (denotation)? Test this by the comparison of some of his words with their synonyms; for instance, in the first paragraph, the word *phenomena* is used—why not *happenings*, *events*, or some other synonym? Or again, in the same paragraph, is the word *diffused*. Compare it with *disseminated*, *distributed*, *scattered*, etc., and determine which word is better fitted for such an address as this. *Utility* in the third sentence from the end of the paragraph may be compared in like manner with *usefulness*, *service*, *advantage*, etc. Throughout the selection, find other words that have a marked intellectual or scientific cast and consider their advantage over more colloquial and less exact terms.

2. Are most of the words of this formal character from the Saxon or the Latin element of the language? Why should words of Greek and Latin derivation be better suited to deal with abstruse ideas and the close discriminations of scholarship than those of Saxon origin?

3. Find instances of plain, homely phrasing in this selection: *dupe*, *ignoramus*, *sealed book* are expressions in the first paragraph of this sort. Substitute more formal and learned terms for these, and note the effect.

4. Do you find any figures of speech in the piece? Does Mill seem to have a wide range of vocabulary? Compare with Stevenson in this respect.

Exercise 1. In order to develop the habit of determining the precise meanings of words, study the words in the following list. They are commonly used carelessly, or with hesitation, by most

people. It might be well to write paragraph discussions of some of them.

Majority and plurality.
Custom and habit.
Adherence and adhesion.
Can and may.
Shall and will.
Set and sit.
Lay and lie.
Effect and affect.
Likely and liable.
Each and every.
Oral and verbal.
While and although.

Exercise 2. Read what Ruskin says about carefulness in the use of words in the lecture, "Of King's Treasuries" in *Sesame and Lilies.* Write a composition on the value of the habit of observing the derivation and the history of words.

Exercise 3. Write a composition of about 500 words in which you explain the scientific style, that is, the choice of words for purposes of science, as distinguished from the literary style. Illustrations may be drawn from the selections from Stevenson and Mill. Huxley's *The Method of Scientific Investigation* (p. 32) and James's *The Religious Attitude* (p. 172) may be drawn upon as illustrations of scientific writing that possesses literary style without loss of exactness and accuracy. The description of the scientific style quoted in the questions upon the selection from James, Newman's remarks of the scientific use of words on page 109, and the following quotation, may be considered in this connection:

"If you are to reach the mind of the reading public by your explanation of the Hegelian system or of the doctrine of state rights, or of the game of football, you must somehow raise your own interest in the subject to a point at which it will make your words vibrate and your style kindle. A public which will yawn over the most learned discussion of its own rights and duties when they are droned forth by a plodding pedant buy many editions of a work which is infused with the interest and intelligence of a man like Mr. Bryce. Students have to go to an impersonal and undigested thesis, if it contains the facts they need. The general public asks more than this: they rightly demand a human view of the facts, illuminated and colored by the warmth of feelings akin to their own. . . . If you are contented

with reaching your little circle of specialists, condense what you have to say into formulæ and the most abstract generalization; thereby you may gain a great reputation for wisdom among a few men. If you want to attain influence over the minds of men as a whole, and perhaps to hand your writings down to posterity, kindle your interest in your subject until it shall set every line that you write glowing with enthusiasm and personal feeling."—GARDINER, *Forms of Prose Literature*, pp. 59–61.

PART II

SPECIAL PROCESSES OF EXPOSITORY WRITING

DEFINITION

DEFINITION OF INSTINCTIVE BEHAVIOUR [1]

C. LLOYD MORGAN

THERE are probably few subjects which have afforded more material for wonder and pious admiration than the instinctive endowments of animals. "I look upon instinct," wrote Addison in one of his graceful essays, "as upon the principle of gravitation in bodies, which is not to be explained by any known qualities inherent in the bodies themselves, nor from any laws of mechanism, but as an immediate impression from the first Mover and the Divine Energy acting in the creatures." In like manner Spence said: "We may call the instincts of animals those faculties implanted in them by the Creator, by which, independent of instruction, observation or experience, and without a knowledge of the end in view, they are all alike impelled to the performance of certain actions tending to the well-being of the individual and the preservation of the species." According to such views, instinct is an ultimate principle the natural genesis of which is beyond the pale of explanation. But similar views were, at the time these passages were written, held to apply, not only to animal behaviour, but also to animal structure. The development of the stag's antler, or of the insect's wing, was also regarded as "an immediate impression from the first Mover and the Divine Energy acting in the creatures." This view, however, is, neither in the case of structure nor in the case of behaviour, that entertained by modern science. It is indeed an expression of opinion concerning the metaphysics of instinct. Leaving the question of ultimate origin precisely where it stood in the times of Addison and of Spence,

[1] Reprinted by permission from *Animal Behaviour* (Macmillan).

modern science seeks to trace the natural antecedents of all natural phenomena, and regards structure and behaviour alike as the products of evolution, endeavouring to explain the manner of their genetic origin in terms of progressive heredity.

Omitting, therefore, all reference to problems which, however important, are beyond the limits of scientific inquiry, we may take as a basis for further discussion Spence's definition, according to which the instincts of animals are those faculties by which, independent of instruction, observation, or experience, and without a knowledge of the end in view, they are all alike impelled to the performance of certain actions tending to their own well-being and the preservation of the species.

Let us first consider the reference of instinctive actions to a *faculty* by which animals are said to be impelled to their performance. Paley also defined instinct as "a *propensity* prior to experience." And unquestionably in the popular conception it is usual to attribute instinctive acts to some such conscious cause. But it will be more convenient, for the present, to consider instinctive behaviour from the objective point of view, as it is presented to our observation; we may then proceed to the further consideration of the conscious concomitants which may be inferred. From the objective point of view, therefore, we may agree with Professor Groos, who says that "the idea of consciousness must be rigidly excluded from any definition of instinct which is to be of practical utility," since "it is always hazardous in scientific investigation to allow an hypothesis which cannot be tested empirically." In this we have the support of Dr. and Mrs. Peckham, whose studies of the life-histories of spiders and wasps are models of careful and patient investigation. "Under the term Instinct," they say, "we place all complex acts which are performed previous to experience, and in a similar manner by all members of the same sex and race, leaving out as non-essential, at this time, the question of whether they are or are not accompanied by consciousness."

It may be said, however, that some reference to the conscious aspect of instinctive behaviour is implied by saying that the

acts are performed without instruction or experience. But the reference at present is wholly negative. We may say, as the result of observation, that instinctive acts are performed under such circumstances as exclude the possibility of guidance in the light of individual experience, and render it in the highest degree improbable that there exists any idea of the end to be attained. But this is a very different position from that of asserting the presence of a positive faculty or propensity which impels an animal to the performance of certain actions. This it is which, from the observational point of view, is unnecessary. For the reference of a given type of observed behaviour to a "propensity" so to behave or to a "faculty" of thus behaving, is no more helpful than the reference of the development of any given type of structure to a "potentiality" so to develop. We may, therefore, without loss of precision, simplify Spence's definition by stating that instinctive behaviour is independent of instruction and experience, and tends to the well-being of the individual and the preservation of the species.

Let us next consider the clause which affirms that instinctive behaviour is prior to experience. This is well in line with the distinction now drawn by biologists between congenital and acquired characters. It refers them to the former category, and implies that the organic mechanism by which they are rendered possible is of germinal origin. This is not, however, universally admitted. Professor Wundt, for example, approaching the subject from the point of view afforded by the study of man and the higher animals, gives to the term a wider meaning, and so defines instinct as to include acquired habits. "Movements," he says, "which originally followed upon simple or compound voluntary acts, but which have become wholly or partly mechanized in the course of individual life, or of generic evolution, we term *instinctive* actions." In accordance with this definition, instincts fall into two groups. Those "which, so far as we can tell, have been developed during the life of the individual, and in the absence of definite individual influences might have remained wholly undeveloped, may be called *acquired* instincts." They have become instinctive

through repetition. "To be distinguished from these acquired human instincts are others which are *connate*." Now, there can be no question that behaviour which has become habitual through frequent repetition is frequently, in popular speech, described as instinctive. We hear it said that the experienced cyclist guides his machine instinctively. And the word is similarly used in many like cases. But we shall find it conducive to precision and clearness of thought to emphasize the distinction between what is acquired in the course of life and what is congenital in the race. And to this end we shall regard behaviour which has "become mechanized in the course of individual life" as due to acquired habit, reserving the term *instinctive* for such behaviour as is independent of individual experience. We shall, in short, so far accept Spence's definition.

In this definition, as in those of the majority of naturalists, it seems to be further implied that instinctive behaviour is of a relatively definite kind, though it is no doubt subject to such variation as is found in animal structure and organization. Mr. Rutgers Marshall, however, in a recent work, protests against any such implication, and urges that "this variableness is so wide that definiteness of reaction cannot for a moment be used as a differentia in relation to instinct without narrowing our conception of the bounds of instinct in a manner to be deplored." "The actions," he says, "connected with the preparation for self-defence, those connected with protection of the young, with nest-building, with migration, etc., these actions are surely to be classed as instinctive; and yet they are exceedingly variable and unpredictable in detail; all that we can predict is the general trend of the varying actions which result from varying stimuli under varying conditions, and which function to some determinate biological end."

Mr. Marshall then proceeds to argue that we are "warranted in speaking of the ethical instincts, of the patriotic instincts, of the benevolent instincts, and of the artistic instincts;" and thus leads up to the position, to be further elaborated in his work, that there exists in man a religious instinct which has fulfilled a function of biological value in the development of

our race. Now, here again there is much in popular usage of the words *instinct* and *instinctive* which lends support, for what it is worth, to Mr. Marshall's very broad conception of the range of instinct. Again and again we hear, in the pulpit and elsewhere, of the religious instinct; we hear, too, of the benevolent, patriotic, and artistic instincts, and more besides. But what we are endeavouring to define is a type of behaviour which, as such, is prior to instruction and experience. Can we affirm that patriotic and religious behaviour conforms to such a type? Is it unquestionably congenital and not acquired? If we are forced to give negative answers to these questions we must regard Mr. Marshall's conception of instinct (one inclusive of multifarious tendencies which have a biological value) as too broad and too vague to be of any service to us at this stage of our study of animal behaviour.

What, then, shall we understand by Spence's phrase that instinct involves the performance of "certain actions"? And how far shall we accept it? We shall take it as implying so much definiteness of behaviour as renders instinctive acts susceptible of scientific investigation, and in this sense shall accept it with some modification of phraseology. We shall freely admit, however, the existence of variations of instinctive behaviour analogous to variations in animal structure. It is the occurrence of such variations that renders the natural selection of instinctive modes of behaviour conceivable. We shall also admit some, nay much, variation in detail. Take, for example, two of the cases which Mr. Marshall cites—nest-building and migration. Both involve, not merely a simple response to a given stimulus, but a complex sequence of actions. In detail there may be much variation even among members of the same species. And yet, can it be questioned that the behaviour as a whole is in each case relatively definite? May we not even say that it is remarkably definite? May we not even go further, and assert that only on the assumption that instinctive behaviour is relatively definite, can we regard it as a subject for scientific investigation, and can we hope to distinguish it from other modes of behaviour?

The next point for consideration in Spence's definition, which we have taken as our text, is his characterization of instinctive acts as "tending to the well-being of the individual and the preservation of the species." Here we have Mr. Marshall with us, for he too lays stress on the fact that instinctive behaviour has reference to a definite biological end. But in saying that the biological end is *the* objective mark of an instinct, he seems to be in error. Because, in the first place, there are other "objective marks," and because, in the second place, this objective mark is not restricted to instinctive behaviour. According to Spence, a further characteristic of instinctive acts is that they are independent of instruction or experience; and this serves to differentiate them from other modes of behaviour which are also subservient to a biological end. Intelligent behaviour, not less than that which we term instinctive, has reference to a biological end. Many intelligent acts, for example, have for their object the well-being of the individual; many subserve race preservation; these bear, every whit as much as instinctive acts, the "objective mark" which Mr. Marshall regards as characteristic of instinct. And if we turn to his subjective criterion—the absence of any conception of the biological end which the behaviour subserves—Mr. Marshall's position is equally untenable. There are thousands of acquired modes of behaviour, dependent on instruction or experience, in which there is, on the subjective side, so far as we can judge, no conception of the biological end to be attained. What can the animal in the early stages of intelligence know of biological ends? Mr. Marshall's subjective criterion applies just as much to a wide range of intelligent behaviour as it does to instinctive actions.

In accepting, therefore, Spence's statement that when animals behave instinctively they perform, without a knowledge of the end in view, certain actions tending to their own well-being and the preservation of the species, we must take it in connection with the preceding limitation, remembering that they are also performed without instruction and experience.

A further point for very brief consideration is suggested by the phrase in which Spence says that animals are *all alike* impelled to the performance of certain actions. As it stands it is too sweeping and general. Still, we do require some explicit statement of the facts which he had in mind when he wrote the words "all alike." And we find it with sufficient exactness in Dr. Peckham's definition, where he comprises under the category of instinctive behaviour "all complex acts which are performed previous to experience, and *in a similar manner by all members of the same sex and race*." This places congenital behaviour in line with morphological structure as a subject for comparative treatment.

One more question remains. What shall we understand by "complex acts"? In the first place, it is well to restrict the term instinctive to *co-ordinated* actions; and this implies the presence of nerve-centres by which the co-ordination is effected. We thus exclude the organic behaviour of plants, since there is no evidence in the vegetable kingdom of co-ordinating centres. In the second place, the co-ordination is, as we have seen, congenital, and not acquired in the course of individual experience. Young water-birds, and indeed young chicks, as soon as they are born, and have recovered from the shock of birth, can swim with definite co-ordination of leg movements. Here the definiteness is not only congenital, but *connate*, if we use the latter term for an instinctive activity which is performed at or very shortly after birth. On the other hand, young swallows cannot fly at birth; they are then too immature, and their wings are not sufficiently developed. But when they are some three weeks old, and the wings have attained functional size and power, little swallows can fly with considerable if not perfect skill. The co-ordination is congenital, for it is not acquired in the course of individual experience; but it is not connate, since it is not exhibited at or shortly after birth. The term *deferred* may be applied to such congenital activities as are thus carried out when the animal has undergone a certain amount of further development after birth.

In the third place, it is customary to distinguish between such

reflex actions as have already been briefly exemplified,[1] and instinctive behaviour. It is, however, by no means easy, if indeed it be possible, to draw any sharp and decisive line of demarcation. Instinct has indeed been well described by Mr. Herbert Spencer as compound reflex action; hence the distinction between instinctive and reflex behaviour turns in large degree on their relative complexity. It would seem, however, that whereas a reflex act—such as the withdrawal of the foot of a sleeping child when the sole is tickled—is a restricted and localized response, involving a particular organ or a definite group of muscles, and is initiated by a more or less specialized external stimulus; instinctive behaviour is a response of the animal as a whole, and involves the co-operation of several organs and of many groups of muscles. Partly initiated by an external stimulus or group of stimuli, it is also, seemingly, determined in part, in a greater degree than reflex action, by internal factors which cause uneasiness or distress, more or less marked, if they do not find their normal instinctive satisfaction. This point, however, may be more profitably discussed in connection with the conscious aspect of instinct. If, then, we say that reflex acts are local responses of the congenital type due to specialized stimuli, while instinctive activities are matters of more general behaviour, usually involving a larger measure of central (as opposed to local or ganglionic) co-ordination, and due to the more widely-spread effects of stimuli in which both external and internal factors co-operate, we shall probably get as near as is possible to the distinction of which we are in search. But it must be remembered that there are cases in which the distinction can hardly be maintained.

We are now in a position to define instinctive behaviour as comprising those complex groups of co-ordinated acts which are, on their first occurrence, independent of experience; which tend to the well-being of the individual and the preservation of the race; which are due to the co-operation of external and internal stimuli; which are similarly performed by all the members of the same more or less restricted group of animals;

[1] That is, in a preceding chapter of the book.—Ed.

but which are subject to variation, and to subsequent modification under the guidance of experience.

QUESTIONS AND EXERCISES

Of prime concern in all scientific thought is accurate, exact definition. This chapter from C. Lloyd Morgan's *Animal Behaviour* furnishes an excellent example of such definition.

1. What is the difference between an expository definition such as this chapter illustrates and the ordinary dictionary definition?

2. Look up the etymology of the word "definition" and see what light is thereby thrown upon the nature of the process of definition.

3. Why does the writer proceed by taking other definitions as his texts, rather than constructing independently a definition of his own? Notice how carefully he scrutinizes each word in Spence's definition.

4. What does the writer mean by "popular usage," and with what other kind of usage is he contrasting it?

5. Note that throughout the discussion the writer is concerned with analyzing and testing the various qualities said to be characteristic of instinct. Of these qualities how many are descriptive of instinct alone and not of any other faculty; that is, how many are true distinguishing marks of instinct?

6. Has the writer succeeded in classing instinct and at the same time distinguished it from other members of its class? Remembering this and the etymology of "definition," explain the nature of the process of definition.

7. Is the writer's choice of words too largely technical?

Exercise 1. Define by a method similar to the one used in the piece just studied, the expression "a technical education," using as your text the following remark from Huxley: "Technical education is that sort of education which is specifically adapted to the needs of men whose business in life is to pursue some trade or profession."

Exercise 2. Newman defines a gentleman as "one who never inflicts pain." Criticize this definition to show its narrowness when taken literally, and construct a better definition of your own.

Exercise 3. Mr. Phelps-Stokes defines a pauper as "a member of society who, through disability or disinclination for self-support by useful service, is supported at the expense of the people." Make your own definition of the term "pauper," following the method of criticizing the different parts of Mr. Phelps-Stokes' definition as in the selection just studied.

Exercise 4. Define by a method similar to the one used in the foregoing selection the term "engineering," using as a basis the following from *The New International Encyclopedia*, "[Engineering embraces] the designing, constructing, and often the operation of structures and machines to serve as ways and means of communication, to secure and utilize Nature's stores of wealth, and to protect life and property from the action of the elements or the carelessness and ignorance of man; all at a minimum outlay of materials and energy."

Exercise 5. President Hyde of Bowdoin College succinctly expresses the objects of college education as follows:

"To be at home in all lands and all ages; to count Nature a familiar acquaintance, and Art an intimate friend; to gain a standard for the appreciation of other men's work and the criticism of your own; to carry the keys of the world's library in your pocket, and feel its resources behind you in whatever task you undertake; to make hosts of friends among the men of your own age who are to be leaders in all walks of life; to lose yourself in generous enthusiasms and coöperate with others for common ends; to learn manners from students who are gentlemen, and form character under professors who are Christians,—this is the offer of the college for the best four years of your life."

Write a fuller explanation of the object of college education, amplifying the different parts of President Hyde's statement.

Read

EQUALITY[1]

JAMES BRYCE

It is now a century and a half since the idea of equality among men began to be constantly discussed, and to influence the world of practice as well as that of abstract thought. It has inspired many schemes, and has been taken as an ideal to be pursued not only in law and politics, but also in sociology and economics. More than once it has become a revolutionary

[1] Adapted from the *Century Magazine*, Vol. XXXIV, p. 459. Reprinted by permission of Honorable James Bryce and the Century Company.

force of tremendous power. Yet the great bulk of mankind have seldom stopped to analyze it, that is to say, to distinguish the various senses in which it is used, and the different bearings it has when applied in different fields of human life. Indeed, much confusion and some errors have arisen from the habit of assuming that because equality is desirable and attainable in certain matters it is desirable and attainable in other and dissimilar matters also, while the excesses of some who have fallen into this error have disposed others to regard it as a foolish and pernicious notion, which ought to be resisted whenever resistance is possible. It is, therefore, worth while to subject the term equality to analysis and examination, with the view of distinguishing the different meanings it bears, or, more precisely, the different import and effect of the conception according as it is applied in one or other kind of subject matter. One cannot hope to present any really new ideas on such a topic. That which may be aimed at is rather to give definiteness and precision to ideas which most of us are apt to hold in a somewhat vague form, and in particular to estimate, in each of the matters whereto it is applied, the practical value of the conception as an ideal toward which the efforts of social or political reformers may be directed.

Let us begin by inquiring what are the various senses in which the phrase equality between men is, or may be, employed.

Six senses may be enumerated in which the phrase is currently used. Two of these refer to man as a pure product of nature, the other four to man as a social being existing under civil institutions of some sort or kind.

The first meaning, though very familiar, is one for which it is hard to find a truly descriptive name, but we may call it spiritual equality. There is a sense in which all men are naturally equal, because all have alike an individual personality which is of supreme value to each. All are alike when they come out of the darkness into this world as mewling babes; all are alike when with failing breath they return again into the darkness. This is the kind of equality denoted by the phrase, "All men are equal in the sight of God." The Almighty is so infinitely above

his creatures that the distinctions between them are as nothing in his eyes. Each is a life-spark, and nothing more. In each, as certain philosophers have said, there dwells a tiny fragment of the universal soul of things. In each personality there is a mystery and even a dignity—the dignity of moral freedom, the importance of which transcends the disparities of man and man, and gives to every life, to every personality, a kind of sacredness. This conception, though one finds it recognized in classical antiquity, derives most of its power from the teachings of Christianity, and has become to most men a distinctly religious conception. Each and every human soul is precious, because each is in direct relation to God, and because each has been deemed to have an infinite future of weal or woe before it.

The other sense in which equality might be said to exist between men, and to be a natural equality, is equality of gifts, physical, intellectual, and moral. Were men equally endowed with strength, intelligence, courage, force, and tenacity of will, there would be a genuine natural equality among them.

As we know, there is no such natural equality, but, on the contrary, the greatest possible disparity, and that even between the nearest kinsfolk, and between persons brought up under the same educational and social influences. Nevertheless, obvious and familiar as is this fact, it has made far less impression on the popular mind than the external points of resemblance between one man and another on the one hand, and, on the other, that equality of personality, which we have just been considering. It is only when diversity and inequality appear in the form of differences of sex, or of race and color, that they receive due recognition; yet differences of sex and of race and color are not greater than the differences which separate the higher from the lower individuals of the same sex and race.

Thus we have, as regards natural man, two salient facts: Between each man, simply as a man, and every other man, there is an equality of soul, an equal worth of personality. There is also between men an inequality of gifts, each man differing from his fellows in physical strength and in physical needs, in intellectual strength and in intellectual tastes, in force of will,

in industry, in perseverance, in rectitude, in capacity for emotion, whether good or bad.

We come now to the four kinds of equality which exist, or may exist, between men in their social as opposed to their purely natural state. These are usually described as civil equality, political equality, social equality, and economic equality.

By civil equality we understand the possession by each man of similar and legal rights in the sphere of private law; that is, equal rights to freedom of speech and action, to personal safety and protection, to the enjoyment of a position in the family, to the holding and disposal of property. This kind of equality is so far from being natural that it is found only in advanced civilizations. Slavery was the rule all over the world, not perhaps among pure savages, but certainly among barbarous and semi-civilized peoples, and has prevailed even in some highly civilized states. Even where slavery has ceased, great disparities as regards private legal rights long continued to exist, as, for instance, in France down to the Revolution. In Britain this equality was established, except as between men and women, at a comparatively early epoch, and its full recognition has been, both there and in the United States, a very potent and beneficial factor in preventing social bitterness and political unrest. We even extend it, for almost all, if not absolutely for all, purposes, to those who are not citizens or subjects of the state.

The term political equality describes the equal enjoyment by all who are citizens of the state of a share in its government, including both the right of voting for persons to be invested with executive or legislative functions, and the right of being one's self eligible for such an executive or legislative post. This is a totally different thing from equality of private legal rights, has been later in its growth, does not prevail so extensively, and does not necessarily or logically follow from civil equality, because the grounds which recommend it are not the same. It is in no country complete as between the sexes. Nevertheless, it tends more and more to make way, and is generally supposed to be the goal toward which nations are traveling.

The term social equality is much more vague, because here

we quit the sphere of law to enter that of social intercourse. It denotes the kind of mutual courtesy and respect which men show to one another when each feels the other to be "as good as himself"—a respect which stands between condescension, on the one hand, and submissiveness on the other. The extent to which it goes depends, of course, upon the particular form of intercourse. There may be a social equality between men as directors of a company or members of a political committee which would not extend to dining at one another's houses, or still less to marrying one another's sisters or daughters. Its growth is generally in proportion to the growth of the last two mentioned kinds of equality; yet it might exist without political equality, and the latter without it.

Lastly, there is economic equality, that is to say, the possession by every man of an equal quantity or value of property, none being either richer or poorer than his neighbor. This state of things has never yet existed, and has no necessary connection with the other kinds of equality, though of course it is only under a régime of political equality that it would be likely to come into being.

So far we have been endeavoring to distinguish and define the different kinds of equality which do exist or may exist among men. Now let us inquire what are the import, the value, and the practical attainability of each of these kinds. Most people tend to assume *a priori* that every species of equality has a sort of presumption in its favor; that it is likely to yield better fruits, both ethically and politically and socially, than inequality; and that it is therefore desirable for all communities to try to work toward it. This tendency deserves to be explained, this alleged presumption to be scrutinized.

That which has been called spiritual equality, the equal worth of each personality or human soul, is now generally admitted by all civilized men, and has become so much a part of our thinking that we forget that there were times when it was not accepted at all. The latest serious attempt to deny it was made in the last days of slavery in the United States, when some few persons, professing to be anthropologists, attempted to show that

African negroes were not members of the human family, but rather a species of highly developed apes. The conception is one which the three great religions of the world all virtually embrace, Mohammedanism having taken it from the Jews and the Christians; and the power it exerts is mainly due to its incorporation in Christian doctrine. The unity of man is correlative to the unity of God. The value of man's soul is measured by the death of the Saviour. It is indeed the sheet-anchor of humanity; for we owe to it all the efforts that are made to help or reclaim those criminals and outcasts whose acts excite repulsion, but who are nevertheless, in another sense, men like ourselves. It is the force which restrains, however imperfectly, the disposition of the stronger races to trample on the weaker, to reduce them to slavery, deny them civil rights, use them like beasts of burden for the benefit of those who need their labor. It is now so firmly rooted everywhere that its continuance may be deemed certain; and no more need here be said regarding it than that it has been the chief cause of that presumption in favor of every sort of equality which has been already referred to. The admission of this principle seems to throw upon any kind of inequality the onus of justifying its existence.

Men reason thus: "All men are born equal; all men die equal; all souls are immortal, and Christ died for all. We brought nothing into the world, and it is certain that we can carry nothing out of it. Why, then, should there be such differences of good and evil fortune, of wealth and poverty, between men? Why should not all have equal rights, equal possessions, and equal happiness?" The New Testament, the American Declaration of Independence, the French principles of 1789, seem to concur in prescribing equality as the normal condition of mankind, or, at any rate, the proper starting-point for every community. Even Bentham's doctrine that the aim of society is to secure the greatest happiness of the greatest number is obliged to assume the equal value of each person, and of the capacity of each for happiness, else the doctrine fails altogether to supply the practical guidance it has undertaken to give. The power which this view of equality as the natural state of man has

exercised is unquestionable. But in trying to apply it to existing social phenomena we are immediately confronted by the other fact, already dwelt upon, viz., the inequality of men as regards their physical and mental powers. Equality of gifts and abilities does not exist, and, so far as we can foresee, never will exist. It does not even seem to come nearer, except to some slight extent, as between the different races of mankind; for though some individuals of remarkable capacity have arisen from among the colored races, no colored race as a whole has brought itself nearly up to the level of the leading white races.

The problems that lie before human society in its onward march are all concerned or involved with these two salient natural facts, an admitted equality between men in one aspect, and a no less palpable inequality between them in another aspect; and as these moral or social problems, like physical problems can be solved, not by running counter to nature, but only by obeying her, like regard must in every effort at solution be had to both facts.

We may now go on to inquire how these two facts, seemingly opposed, yet both true, have worked upon the relations of men in the social sphere. And this brings us to the four forms of equality which exist in that sphere, viz., civil, political, social, and economic equality.

Civil equality, equality of rights in the field of private law, is so generally admitted to be wholesome for the whole community as to have become a good practical test of the higher or lower level of civilization which any state has reached. It is now virtually universal in Europe (except, of course, in semi-civilized Turkey), and in all the colonies of European nations. Its acceptance has been due partly to sentiment and sympathy, but largely also to an experience of the evils of inequality as giving rise to arrogance and injustice on the part of privileged classes, and exposing the less privileged to harsh treatment. The sense of wrong produces discontent, and discontent disturbs the state. The very term equity, which our lawyers have drawn from the favorite expression of the Roman lawyers, *æquum et bonum*, indicates the tendency to find in equality

of treatment a foundation for justice, and the easiest way out of the endless complications and difficulties to which the preference of one class of persons over another gives rise. The tendency to level down and level up became strong in jurisprudence before it had established itself in politics. Economic changes worked the same way; for when wealth was acquired by persons belonging to the inferior classes, they used it to evade and ultimately to overthrow those provisions of the old law which placed them at a disadvantage compared with men of higher rank. To one who reviews the progress of the world during the last four centuries, no small part of that progress seems to consist in or to issue from civil inequality, and its steady and striking growth is a striking illustration of the power of moral forces, of truth, reason, and good feeling. These have been more important agents in creating it than any revolts of the oppressed; and, indeed, it was they that enabled some of those revolts to succeed.

The equality of men in respect of political rights has made far slower advances, and involves considerations very different from those which govern our view of equality of civil rights. We may define it as meaning the equal right of every citizen to share in the government of a state, whether as a voter or as eligible for any office or post. The idea of such equality is very modern, the realization of it still more recent, and hardly anywhere complete. So far from its having been the original condition of mankind, it would seem to have never existed in any primitive people which had reached even the rudest political organization. The dominance of one man, or a few men, over the majority is everywhere the patent fact, and the circle of those who share in political power was very slowly extended. Such extension usually comes, as in the case of the equality of private civil rights, partly through the discontent of the excluded mass, who see, or think they see, that the authority of the privileged few is used to their prejudice, partly by a feeling, which gradually spreads among the most enlightened members of the privileged class, that no set of people can be trusted to legislate for others, and that a government is more stable when its base

is broad. Where the few rule the many, the many will always blame the few for any mistakes or misfortunes. When they obtain their share, they have only themselves to blame. Accordingly there has been established in modern times and in advanced nations a sort of presumption in favor of a wide political franchise and universal eligibility for office, as making probably for the general good, but anyhow for the general contentment. This, however, is only a presumption. There is another side to the question. Equality of civil rights is almost certainly a good thing, for it can hardly be misused. Equality of political rights may readily be misused; for it requires capacity, and capacity may be wanting. Where political power is committed to a mass of people who are ignorant and untrained, and where this mass is not disposed to be guided by those who are wiser and more instructed, it may choose bad rulers and sanction foolish measures. Thus a suffrage suitable to the white population of Massachusetts may not be suitable to the predominantly colored population of Louisiana. In every case the risk of this evil must be set against the presumptive advantages already mentioned; and the difficulty of balancing them may be illustrated from the division of opinion among intelligent men and women which exists on the question of woman suffrage. There is, therefore, no general rule to be laid down on the subject. In every case a balance must be struck between probable gains and probable dangers. Regard must be had to time, place, and circumstance; the application of abstract principles and *à priori* doctrines, such as were so potent among the French from 1789 to 1792, and in the United States for two generations after 1776, must be carefully eschewed.

We come next to social equality, and find ourselves passing out of the sphere of law into that of general human intercourse. Is it desirable that there should be no social ranks or grades, and that (apart from office and from age, two things which have usually and rightly commanded defference) each man should treat every other man as being absolutely on his own level?

Here we are confronted by the old contradiction between natural equality, in the sense of spiritual equality of every

human being, and natural inequality, in the sense of the great diversity of intellectual and moral gifts between different persons. The former would seem to forbid social distinctions; for if each personality is of the same value, it ought to obtain the same respect from others. The latter, however, shows us some persons immensely superior in integrity, in force of character, in all the powers which enable a man to lead or to edify or to delight his fellow-men. The instinct which defers to such kind of superiority is both natural and reasonable, and the instinct which defers to wealth and power is, at any rate, natural. Moreover, differences of intellect and of education produce differences of taste; differences of wealth produce differences of habits of life; and such differences necessarily affect social intercourse. The establishment of economic communism, or of an absolute equality of conditions, would remove the latter; but the former would still subsist, and would create, if not a barrier, at least a certain disinclination to intimacy between the person who loves literature or art and the person who loves only foot-ball or his dinner.

The tendency to establish distinctions of rank is deep-rooted and universal. Some of us would not consider that there was much difference, if any, between the vocation of a seller of peanuts and that of an organ grinder. The former is nearly as nomadic a person as the latter. Nevertheless, in New York the distinction is so great that the former does not permit his children to play with the children of the latter. When a tendency is naturally so strong, the attempt to ignore its results may produce an artificial state of things disagreeable to everybody, as the attempt of some idealists to make their domestic servants sit down to meals along with them has been resisted by the servants themselves.

On a review of the whole matter, it would appear, that while the principle of social equality does point to the extinction of all artificial and legal distinctions of rank, already accomplished in the United States, and does prescribe the same courtesy and consideration toward all persons alike, it cannot venture to ignore differences which spring from diversities of knowledge, culture,

and taste; for these, too, are natural, and operate outside the sphere of law and social custom. Neither has it been able to overcome the differences for which wealth, as affecting men's habits of life, is unanswerable. The apostles of equality may, however, reply that inequalities of wealth are themselves artificial, and ought to be got rid of. And this brings us to the last kind of equality we have to consider—that of economic conditions.

Perhaps the strongest influence in bringing this question to the front has been the complete attainment by the masses, in most civilized countries, of political power. Their fathers strove for it in the belief that it would immensely improve their condition. Now that they have got it, the old inequalities of wealth remain; and though the poor of to-day are in most countries better off than the poor of a century ago, those inequalities are fully as palpable. "Of what use, then," thus do many feel and say—"has it been to conquer political power, if we are not by means of it to better our own condition?"

These ideas, which are not confined to the poor, but are reinforced by the sympathy of imaginative and benevolent minds among the wealthier class, have now much force at their command. They meet us everywhere. They raise in many forms what is the main question that occupies the thoughts of thinking men. And they have behind them—do not let us, whatever error or confusion may be found to lurk in them, forget this fact—they have behind them the notion that they are suggested by nature, by justice, and by the largest conception of the common good of mankind.

When, however, we come to criticize these ideas and the source assigned to them, the following observations occur.

First of all, be it noted that there never has been in the world such a state of natural equality as many have dreamed of. Even in the stone age, one savage had more flint hatchets or a bigger deer skin than the other tribesmen. As soon as a race begins to have any sort of an organization, as soon, for instance, as it reaches the stage in which the Romans found the Britons of antiquity, or in which our settlers have found the North

American Indians and the Kafirs—inequalities of property are conspicuous.

Secondly, it is not law that creates inequality of property. It is, in the first instance, strength, physical or intellectual; that is to say, inequality is due to natural, not to artificial, causes. When law appears, it does no more than recognize and protect the inequality which it finds subsisting; and if we can imagine law withdrawn, inequality would be greater than it is now, because the weaker would have no security for what they possess, since force, whether of body or of craft and will, would dominate. If equality of goods is ever to be established, it will have to be established by law, either by forbidding the appropriation of any articles, i. e. by destroying the conception of private property, and giving each man the protection of the state in taking a part of whatever his neighbor has, or else by continually restoring through legal action an equilibrium of goods which natural causes are perpetually disturbing. This will be the hardest task law has ever undertaken, because law will have to steer straight in the teeth of the strong blast of nature. If ten men were to be started, on Monday morning, with equal property, and left to themselves for six days, no two would be found to have equal property on Saturday night, because in no two would the faculty of acquiring and the habit of spending be the same.

Thirdly, where the enforcement of law is perfect, that is to say, where the action of courts, and of the authority which carries out their decisions, is certain, the qualities which tend to produce inequality of property are different from those which produced it in rude and disorderly times. In those times physical strength and physical courage were the most important factors. In perfectly settled societies intelligence and the habit of saving must tell. Will evidently tells in all states of society, and will is one of the qualities in which men most differ from one another. Of course it is not necessarily the highest forms of intelligence that must subserve the acquisitions of property. No poet before Tennyson ever made a fortune by his gift. No philosopher has ever yet grown rich by his philosophy.

Only in very recent times have a few great inventors been able to reap the harvest of their intellectual labors. It is by the power of devising schemes and conducting large commercial or financial operations that the largest masses of property are accumulated in one hand, and the type of capacity that leads to wealth is to be found in such a man as the late Mr. Jay Gould. This has caused a certain prejudice against the working of laws which permit a capacity not necessarily beneficial, and possibly harmful, to mankind to achieve conspicuous success. But no one has shown how this capacity can be held in check without overthrowing the entire legal basis on which modern communities rest.

When we scrutinize the grounds of the desire for equality, a fourth observation presents itself. Inequality of property is not an evil *per se*. It is not in itself harmful to A—that is, it is no diminution of his happiness—that B should have more grain or more cattle or more money than he has himself. A may have other things which are better than B's property, even as the psalmist says: "I had more joy than they when their corn and their oil were increased." M may have stronger health, or a better wife or children, a greater faculty of intellectual enjoyment, than P has,—things which have more to do with happiness than has any amount of property,—and M's possession of these advantages does not diminish P's happiness or increase his wretchedness, for they depend on what P himself has or lacks. So if I have $1,000, I am none the worse off because you have $10,000. It is not your excess that affects my well-being, but my own sufficient or insufficient provision. That which is desirable is to have enough, not as much as another man has or needs, but as much as I myself need. But what is enough? It is a variable conception; it is, in point of quantity, no more the same for every man than is a man's stature or his appetite. It depends for each man upon his physical and intellectual needs and tastes, and the wise man is he who regulates his conception of it by his own needs and tastes, and not by those of his neighbors, which may sometimes enlighten, but are just as likely to mislead, his own judgment Many persons who perceive that

M has less than enough and P more than enough, jump at the conclusion that the proper way to rectify the mischief is to take from P his superfluity and bestow it upon M. But though this is a very common confusion of ideas, it is none the less a confusion. It may be bad for a man to have too much. It is certainly bad for him to have too little. But the evil lies not in the inequality of possessions, but in the excess or defect; and the only sense in which poor M suffers from witnessing P's wealth is that the spectacle accentuates by contrast the evils of his own condition. Just in the same way P, who is stiff with rheumatism and has been forsaken by his wife, may envy the robust health and happy home of M.

Here, therefore, we note a capital difference between inequality of economic conditions and inequality of civil rights or political rights. In the two last-named cases, one man's gain is another man's loss. If X has a wider compass of civil rights than Y, Y necessarily suffers, because the law enables X to prevail against him when a dispute arises. In Turkey, for instance, a Mussulman may with practical impunity kill a Christian rajah, but a Christian rajah cannot with impunity kill a Mussulman. So if X (a class of persons) enjoy the suffrage, and Y (another class) do not, it usually happens that the legislation which class X enacts is calculated to benefit the privileged and to depress the excluded class. As one of the scales rises, so the other sinks. With property it is otherwise. Except in one class of cases, P's abundance does not come from M's deficiency, and P's share might be reduced without increasing M's. That one class of cases is where the thing of which men hold unequal amounts is itself limited in quantity. If P draws off two-thirds of the water of a stream to irrigate his meadow, he leaves only one-third to be used by M, and the only way to give M an equal share is to deprive P of the one-sixth which represents his excess. The great instance of this sort of thing is of course land, and the contents of land; and accordingly the observation just made cannot be applied to land in any country where it has become scarce.

It may be said that in any given industrial undertaking, such as a factory, the profits are limited, and therefore the more

P gets, so much the less is there for C, D, and E. It would lead us too far afield to enter this field of controversy, and in particular to discuss the nature of capital. But it deserves to be noted that in most industrial undertakings the contributions of the different co-workers differ in value. P may bring scientific genius, C may bring commercial experience, D may bring consummate manual skill, while E, F, G, and H have only physical strength to contribute; and of the whole profits of the undertaking, three-fourths may be traceable to P's inventive genius, which a reward of one-seventh of the profits would not be sufficient to secure.

Are there then no real objections to inequality of economic conditions? Certainly there are; but they are objections grounded not on abstract considerations of nature and justice, but upon the results which inequality has been found in practice to produce. Neither are they objections to inequality *per se*, but only to its extreme forms, where accumulations of property in a few hands are huge and conspicuous. Such accumulations create a highly luxurious class, many of whose members remain idle and useless all their lives, while others form habits and try to follow a style of living unsuited to their means. The holders of vast fortunes acquire undue power, they have undue influence with rulers, they may corrupt legislators, they may pervert the power of the state to serve their selfish ends. Their wealth, if ostentatiously displayed or squandered upon unworthy objects, excites envy, breeds discontent, and may furnish incitements to the spirit of plunder. There have no doubt been states in which great inequalities of fortune existed, but which were nevertheless comparatively stable and well governed. In such states, however, the inequalities of fortune corresponded to inequalities in political power and social influence. Very different is the condition of some of our modern states, wherein fortunes still more disproportionately huge have been disjoined from any power and any respect save that which mere wealth may command. There is therefore a *prima facie* case, grounded nowise on abstract principles, but on observation and experience, not indeed for a compulsory equalization, but for a re-

duction of extreme inequalities, of wealth. How can such a reduction be effected? The problem is a difficult one, for when you begin to interfere with nature you will get into trouble. Moreover, you may injure the man who has too little, whom you wish to benefit, as much as, or more than, the man who has far too much. Indeed the latter, though the defenders of the present system are chiefly concerned on his behalf, is less likely to suffer, for the luxury bred by excessive wealth is a bad thing for him, since it increases his temptations. The main difficulties are ethical, and I state them rather than the economic difficulties, because the latter would require a more elaborate examination. If by legislation you take property away from the rich man, the property he has earned or inherited, you shock confidence, and you weaken the motives for thrift and foresight which operate on the mind of the rich. If by legislation you give property to the poorer man, you weaken the natural incentive to exertion which the need of providing for himself creates. It is no doubt said that before long a new set of ethical views and habits will arise which will supply the place of those set aside. This is a question too large to discuss here, and it is, of course, a highly speculative one, outside the range of such experience as mankind has so far enjoyed.

QUESTIONS AND EXERCISES

This selection may be studied in connection with the preceding one on *Instinctive Behaviour*, as further illustrative of definition. Outside the realm of science, there are few words in common use whose meanings are sharply defined and universally accepted. The explanation of this is probably to be found in the fact that each person acquires the larger part of his vocabulary not from dictionaries or such sources, which tend to uniformity in usage, but from hearing words bandied about from mouth to mouth, each user taking broad liberty in fitting them to his personal needs and exigencies. In consequence, confusion such as Mr. Bryce is trying to clear up in connection with "equality" is present in the employment of dozens of other words in common use.

1. The purpose of the essay is definitely stated in the last sentence of the first paragraph. Is it consistently carried out? The first

four paragraphs are perfectly clear and orderly: make a careful outline of the remainder of the essay, paragraph by paragraph, to see if it is as clear and logical.

2. From the standpoint of processes of definition, this selection should be compared carefully with the preceding one on instinct. It will be noted that the procedure is somewhat different. Morgan is not trying to mark clearly the various senses in which the word instinct is or may be used, but, as far as possible, to bound or limit the idea, instinct, by making his definition include all that pertains to instinct while it excludes all that does not. Bryce, on the other hand, is not trying to limit the broad term, equality, to find the boundaries between it and other terms, but to define the narrower terms which it embraces—spiritual equality, natural equality, etc. In the latter case, from one point of view we have six separate and distinct definitions; but from another point of view these six all help to define the broader term equality by acquainting us with its entire content.

Exercise 1. The following terms are, in popular parlance, of somewhat uncertain meaning and application. Select one of them for a treatment similar to that accorded by Bryce to equality.

Education.	Democracy.
Culture.	Liberty.
Science.	Imperialism.
Success.	Romance.
Progress.	Charity.
Socialism.	College Spirit.

Use one? Define these as Bryce's equality

THE RELIGIOUS ATTITUDE[1]

WILLIAM JAMES

MOST books on the philosophy of religion try to begin with a precise definition of what its essence consists of. Some of these would-be definitions may possibly come before us in later portions of this course, and I shall not be pedantic enough to enumerate any of them to you now. Meanwhile the very fact

[1] Reprinted from *The Varieties of Religious Experience*, by permission of the author.

that they are so many and so different from one another is enough to prove that the word "religion" cannot stand for any single principle or essence, but is rather a collective name. The theorizing mind tends always to the over-simplification of its materials. This is the root of all that absolutism and one-sided dogmatism by which both philosophy and religion have been infested. Let us not fall immediately into a one-sided view of our subject, but let us rather admit freely at the outset that we may very likely find no one essence, but many characters which may alternately be equally important in religion. If we should inquire for the essence of "government," for example, one man might tell us it was authority, another submission, another police, another an army, another an assembly, another a system of laws; yet all the while it would be true that no concrete government can exist without all these things, one of which is more important at one moment and others at another. The man who knows governments most completely is he who troubles himself least about a definition which shall give their essence. Enjoying an intimate acquaintance with all their peculiarities in turn, he would naturally regard an abstract conception in which these were unified as a thing more misleading than enlightening. And why may not religion be a conception equally complex?

Consider also the "religious sentiment" which we see referred to in so many books, as if it were a single sort of mental entity.

In the psychologies and in the philosophies of religion, we find the authors attempting to specify just what entity it is. One man allies it to the feeling of dependence; one makes it a derivative from fear; others connect it with the sexual life; others still identify it with the feeling of the infinite; and so on. Such different ways of conceiving it ought of themselves to arouse doubt as to whether it possibly can be one specific thing; and the moment we are willing to treat the term "religious sentiment" as a collective name for the many sentiments which religious objects may arouse in alternation, we see that it probably contains nothing whatever of a psychologically specific

nature. There is religious fear, religious love, religious awe, religious joy, and so forth. But religious love is only man's natural emotion of love directed to a religious object; religious fear is only the ordinary fear of commerce, so to speak, the common quaking of the human breast, in so far as the notion of divine retribution may arouse it; religious awe is the same organic thrill which we feel in a forest at twilight, or in a mountain gorge; only this time it comes over us at the thought of our supernatural relations; and similarly of all the various sentiments which may be called into play in the lives of religious persons. As concrete states of mind, made up of a feeling *plus* a specific sort of object, religious emotions of course are psychic entities distinguishable from other concrete emotions; but there is no ground for assuming a simple abstract "religious emotion" to exist as a distinct elementary mental affection by itself, present in every religious experience without exception.

As there thus seems to be no one elementary religious emotion, but only a common storehouse of emotions upon which religious objects may draw, so there might conceivably also prove to be no one specific and essential kind of religious object, and no one specific and essential kind of religious act.

The field of religion being as wide as this, it is manifestly impossible that I should pretend to cover it. My lectures must be limited to a fraction of the subject. And, although it would indeed be foolish to set up an abstract definition of religion's essence, and then proceed to defend that definition against all comers, yet this need not prevent me from taking my own narrow view of what religion shall consist in *for the purpose of these lectures*, or, out of the many meanings of the word, from choosing the one meaning in which I wish to interest you particularly, and proclaiming arbitrarily that when I say "religion" I mean *that*. This, in fact, is what I must do, and I will now preliminarily seek to mark out the field I choose.

One way to mark it out easily is to say what aspects of the subject we leave out. At the outset we are struck by one great partition which divides the religious field. On the one side of

it lies institutional, on the other personal religion. As M. P. Sabatier says, one branch of religion keeps the divinity, another keeps man most in view. Worship and sacrifice, procedures for working on the dispositions of the deity, theology and ceremony and ecclesiastical organization, are the essentials of religion in the institutional branch. Were we to limit our view to it, we should have to define religion as an external art, the art of winning the favor of the gods. In the more personal branch of religion it is on the contrary the inner dispositions of man himself which form the center of interest, his conscience, his deserts, his helplessness, his incompleteness. And although the favor of the God, as forfeited or gained, is still an essential feature of the story, and theology plays a vital part therein, yet the acts to which this sort of religion prompts are personal not ritual acts, the individual transacts the business by himself alone, and the ecclesiastical organization, with its priests and sacraments and other go-betweens, sinks to an altogether secondary place. The relation goes direct from heart to heart, from soul to soul, between man and his maker.

Now in these lectures I propose to ignore the institutional branch entirely, to say nothing of the ecclesiastical organization, to consider as little as possible the systematic theology and the ideas about the gods themselves, and to confine myself as far as I can to personal religion pure and simple. To some of you personal religion, thus nakedly considered, will no doubt seem too incomplete a thing to wear the general name. "It is a part of religion," you will say, "but only its unorganized rudiment; if we are to name it by itself, we had better call it man's conscience or morality than his religion. The name 'religion' should be reserved for the fully organized system of feeling, thought, and institution, for the Church, in short, of which this personal religion, so called, is but a fractional element."

But if you say this, it will only show the more plainly how much the question of definition tends to become a dispute about names. Rather than prolong such a dispute, I am willing to accept almost any name for the personal religion of which I propose to treat. Call it conscience or morality, if you your-

selves prefer, and not religion—under either name it will be equally worthy of our study. As for myself, I think it will prove to contain some elements which morality pure and simple does not contain, and these elements I shall soon seek to point out; so I will myself continue to apply the word "religion" to it; and in the last lecture of all, I will bring in the theologies and the ecclesiasticisms, and say something of its relation to them.

In one sense at least the personal religion will prove itself more fundamental than either theology or ecclesiasticism. Churches, when once established, live at second-hand upon tradition; but the *founders* of every church owed their power originally to the fact of their direct personal communion with the divine. Not only the superhuman founders, the Christ, the Buddha, Mahomet, but all the originators of Christian sects have *been* in this case;—so personal religion should still seem the primordial thing, even to those who continue to esteem it incomplete.

There are, it is true, other things in religion chronologically more primordial than personal devoutness in the moral sense. Fetishism and magic seem to have preceded inward piety historically—at least our records of inward piety do not reach back so far. And if fetishism and magic be regarded as stages of religion, one may say that personal religion in the inward sense and the genuinely spiritual ecclesiasticisms which it founds are phenomena of secondary or even tertiary order. But, quite apart from the fact that many anthropologists—for instance, Jevons and Frazer—expressly oppose "religion" and "magic" to each other, it is certain that the whole system of thought which leads to magic, fetishism, and the lower superstitions may just as well be called primitive science as called primitive religion. The question thus becomes a verbal one again; and our knowledge of all these early stages of thought and feeling is in any case so conjectural and imperfect that further discussion would not be worth while.

Religion, therefore, as I now ask you arbitrarily to take it, shall mean for us *the feelings, acts, and experiences of individual*

men in their solitude, so far as they apprehend themselves to stand in relation to whatever they may consider the divine. Since the relation may be either moral, physical, or ritual, it is evident that out of religion in the sense in which we take it, theologies, philosophies, and ecclesiastical organizations may secondarily grow. In these lectures, however, as I have already said, the immediate personal experiences will amply fill our time, and we shall hardly consider theology or ecclesiasticism at all.

We escape much controversial matter by this arbitrary definition of our field. But, still, a chance of controversy comes up over the word "divine," if we take it in the definition in too narrow a sense. There are systems of thought which the world usually calls religious, and yet which do not positively assume a God. Buddhism is in this case. Popularly, of course, the Buddha himself stands in place of a God; but in strictness the Buddhistic system is atheistic. Modern transcendental idealism, Emersonianism, for instance, also seems to let God evaporate into abstract Ideality. Not a deity *in concreto*, not a superhuman person, but the immanent divinity in things, the essentially spiritual structure of the universe, is the object of the transcendentalist cult. In that address to the graduating class at Divinity College in 1838 which made Emerson famous, the frank expression of this worship of mere abstract laws was what made the scandal of the performance.

"These laws," said the speaker, "execute themselves. They are out of time, out of space, and not subject to circumstance: Thus, in the soul of man there is a justice whose retributions are instant and entire. He who does a good deed is instantly ennobled. He who does a mean deed is by the action itself contracted. He who puts off impurity thereby puts on purity. If a man is at heart just, then in so far is he God; the safety of God, the immortality of God, the majesty of God, do enter into that man with justice. If a man dissemble, deceive, he deceives himself, and goes out of acquaintance with his own being. Character is always known. Thefts never enrich; alms never impoverish; murder will speak out of stone walls. The least admixture of a lie—for example, the taint of vanity, any attempt to make a good impression, a favorable appearance—will instantly vitiate the effect. But speak the truth, and all things alive

or brute are vouchers, and the very roots of the grass underground there do seem to stir and move to bear you witness. For all things proceed out of the same spirit, which is differently named love, justice, temperance, in its different applications, just as the ocean receives different names on the several shores which it washes. In so far as he roves from these ends, a man bereaves himself of power, of auxiliaries. His being shrinks . . . he becomes less and less, a mote, a point, until absolute badness is absolute death. The perception of this law awakens in the mind a sentiment which we call the religious sentiment, and which makes our highest happiness. Wonderful is its power to charm and to command. It is a mountain air. It is the embalmer of the world. It makes the sky and the hills sublime, and the silent song of the stars is it. It is the beatitude of man. It makes him Illimitable when he says 'I ought'; when love warns him; when he chooses, warned from on high, the good and great deed; then, deep melodies wander through his soul from supreme wisdom. Then he can worship, and be enlarged by his worship; for he can never go behind this sentiment. All the expressions of this sentiment are sacred and permanent in proportion to their purity. [They] affect us more than all other compositions. The sentences of the olden time, which ejaculate this piety, are still fresh and fragrant. And the unique impression of Jesus upon mankind, whose name is not so much written as ploughed into the history of this world, is proof of the subtle virtue of this infusion."

Such is the Emersonian religion. The universe has a divine soul of order, which soul is moral, being also the soul within the houl of man. But whether this soul of the universe be a mere quality like the eye's brilliancy or the skin's softness, or whether it be a self-conscious life like the eye's seeing or the skin's feeling, is a decision that never unmistakably appears in Emerson's pages. It quivers on the boundary of these things, sometimes leaning one way, sometimes the other, to suit the literary rather than the philosophic need. Whatever it is, though, it is active. As much as if it were a God, we can trust it to protect all ideal interests and keep the world's balance straight. The sentences in which Emerson, to the very end, gave utterance to this faith are as fine as anything in literature: "If you love and serve men, you cannot by any hiding or stratagem escape

the remuneration. Secret retributions are always restoring the level, when disturbed, of the divine justice. It is impossible to tilt the beam. All the tyrants and proprietors and monopolists of the world in vain set their shoulders to heave the bar. Settles forevermore the ponderous equator to its line, and man and mote, and star and sun, must range to it, or be pulverized by the recoil."

Now it would be too absurd to say that the inner experiences that underlie such expressions of faith as this and impel the writer to their utterance are quite unworthy to be called religious experiences. The sort of appeal that Emersonian optimism, on the one hand, and Buddhistic pessimism, on the other, make to the individual and the sort of response which he makes to them in his life are in fact indistinguishable from, and in many respects identical with, the best Christian appeal and response. We must therefore, from the experimental point of view, call these godless or quasi-godless creeds "religions;" and accordingly when in our definition of religion we speak of the individual's relation to "what he considers the divine," we must interpret the term "divine" very broadly, as denoting any object that is god*like*, whether it be a concrete deity or not.

But the term "godlike," if thus treated as a floating general quality, becomes exceedingly vague, for many gods have flourished in religious history, and their attributes have been discrepant enough. What then is that essentially godlike quality —be it embodied in a concrete deity or not—our relation to which determines our character as religious men? It will repay us to seek some answer to this question before we proceed farther.

For one thing, gods are conceived to be the first things in the way of being and power. They overarch and envelop, and from them there is no escape. What relates to them is the first and last word in the way of truth. Whatever then were most primal and enveloping and deeply true might at this rate be treated as godlike, and a man's religion might thus be iden-

tified with his attitude, whatever it might be, towards what he felt to be the primal truth.

Such a definition as this would in a way be defensible. Religion, whatever it is, is a man's total reaction upon life, so why not say that any total reaction upon life is a religion? Total reactions are different from casual reactions, and total attitudes are different from usual or professional attitudes. To get at them you must go behind the foreground of existence and reach down to that curious sense of the whole residual cosmos as an everlasting presence, intimate or alien, terrible or amusing, lovable or odious, which in some degree every one possesses. This sense of the world's presence, appealing as it does to our peculiar individual temperament, makes us either strenuous or careless, devout or blasphemous, gloomy or exultant, about life at large; and our reaction, involuntary and inarticulate and often half unconscious as it is, is the completest of all our answers to the question, "What is the character of this universe in which we dwell?" It expresses our individual sense of it in the most definite way. Why then not call these reactions our religion, no matter what specific character they may have? Non-religious as some of these reactions may be, in one sense of the word "religious," they yet belong to *the general sphere of the religious life*, and so should generically be classed as religious reactions. "He believes in No-God, and he worships him," said a colleague of mine of a student who was manifesting a fine atheistic ardor; and the more fervent opponents of Christian doctrine have often enough shown a temper which, psychologically considered, is indistinguishable from religious zeal.

But so very broad a use of the word "religion" would be inconvenient, however defensible it might remain on logical grounds. There are trifling, sneering attitudes even towards the whole of life; and in some men these attitudes are final and systematic. It would strain the ordinary use of language too much to call such attitudes religious, even though, from the point of view of an unbiased critical philosophy, they might conceivably be perfectly reasonable ways of looking upon life. Voltaire, for example, writes thus to a friend, at the age of

seventy-three: "As for myself," he says, "weak as I am, I carry on the war to the last moment, I get a hundred pike-thrusts, I return two hundred, and I laugh. I see near my door Geneva on fire with quarrels over nothing, and I laugh again; and, thank God, I can look upon the world as a farce even when it becomes as tragic as it sometimes does. All comes out even at the end of the day, and all comes out still more even when all the days are over."

Much as we may admire such a robust old gamecock spirit in a valetudinarian, to call it a religious spirit would be odd. Yet it is for the moment Voltaire's reaction on the whole of life. *Je m'en fiche* is the vulgar French equivalent for our English ejaculation "Who cares?" And the happy term *je m'en fichisme* recently has been invented to designate the systematic determination not to take anything in life too solemnly. "All is vanity" is the relieving word in all difficult crises for this mode of thought, which that exquisite literary genius Renan took pleasure, in his later days of sweet decay, in putting into coquettishly sacrilegious forms which remain to us as excellent expressions of the "all is vanity" state of mind. Take the following passage, for example,—we must hold to duty, even against the evidence, Renan says,—but he then goes on:

"There are many chances that the world may be nothing but a fairy pantomime of which no God has care. We must therefore arrange ourselves so that on neither hypothesis we shall be completely wrong. We must listen to the superior voices, but in such a way that if the second hypothesis were true we should not have been too completely duped. If in effect the world be not a serious thing, it is the dogmatic people who will be the shallow ones, and the worldly minded whom the theologians now call frivolous will be those who are really wise.

"*In utrumque paratus*, then. Be ready for anything—that perhaps is wisdom. Give ourselves up, according to the hour, to confidence, to skepticism, to optimism, to irony, and we may be sure that at certain moments at least we shall be with the truth. . . . Good-humor is a philosophic state of mind; it seems to say to Nature that we take her no more seriously than she takes us. I maintain that one should always talk of philosophy with a smile. We owe it

to the Eternal to be virtuous, but we have the right to add to this tribute our irony as a sort of personal reprisal. In this way we return to the right quarter jest for jest; we play the trick that has been played on us. Saint Augustine's phrase: *Lord, if we are deceived, it is by thee!* remains a fine one, well suited to our modern feeling. Only we wish the Eternal to know that if we accept the fraud, we accept it knowingly and willingly. We are resigned in advance to losing the interest on our investments of virtue, but we wish not to appear ridiculous by having counted on them too securely."

Surely all the usual associations of the word "religion" would have to be stripped away if such a systematic *parti pris* of irony were also to be denoted by the name. For common men "religion," whatever more special meanings it may have, signifies always a *serious* state of mind. If any one phrase could gather its universal message, that phrase would be, "All is *not* vanity in this Universe, whatever the appearances may suggest." If it can stop anything, religion as commonly apprehended can stop just such chaffing talk as Renan's. It favors gravity, not pertness; it says "hush" to all vain chatter and smart wit.

But if hostile to light irony, religion is equally hostile to heavy grumbling and complaint. The world appears tragic enough in some religions, but the tragedy is realized as purging, and a way of deliverance is held to exist. We shall see enough of the religious melancholy in a future lecture; but melancholy, according to our ordinary use of language, forfeits all title to be called religious when, in Marcus Aurelius's racy words, the sufferer simply lies kicking and screaming after the fashion of a sacrificed pig. The mood of a Schopenhauer or a Nietzsche,—and in a less degree one may sometimes say the same of our own sad Carlyle—though often an ennobling sadness is almost as often only peevishness running away with the bit between its teeth. The sallies of the two German authors remind one, half the time, of the sick shriekings of two dying rats. They lack the purgatorial note which religious sadness gives forth.

There must be something solemn, serious, and tender about any attitude which we denominate religious. If glad, it must

not grin or snicker; if sad, it must not scream or curse. It is precisely as being *solemn* experiences that I wish to interest you in religious experiences. So I propose—arbitrarily again, if you please—to narrow our definition once more by saying that the word "divine," as employed therein, shall mean for us not merely the primal and enveloping and real, for that meaning if taken without restriction might well prove too broad. The divine shall mean for us only such a primal reality as the individual feels impelled to respond to solemnly and gravely, and neither by a curse nor a jest.

QUESTIONS AND EXERCISES

In this example of definition, taken from Professor James's *The Varieties of Religious Experience*, there are several interesting points of contrast with preceding definitions. Professor James wishes to carry over into careful, accurate, scientific discussion a word which, of all words in popular parlance, is most open to varying shades of meaning, and, in the popular mind, is most bound up with innumerable prejudices. The difficulty and delicacy of his task will be readily apparent. James declines to use the general term religion until he has discussed for his hearers just exactly how much of its meaning he is using for his present purposes. His further task is to secure the consent of his audience to the phase of meaning which he has singled out. The selection is notable for the finish and amenity of its style. It shows how a personal reaction to the facts and an interest in the subject may enliven and color an abstract discussion, without producing any sacrifice of exactness or logicality.

1. Analyze carefully and account for the steps by which James leads up to his first formal definition.

2. The next step is the explanation of a troublesome word in the definition itself. Note carefully the manner in which the interpretation of the word *divine* is presented.

3. Compare James's method with that employed by Morgan and with that employed by Bryce. Do you note any significant differences, or are all three methods essentially the same?

4. How does James make the limited sense in which he uses his term seem to his audience satisfactory?

5. How does he give concreteness to his definition?

6. Is each step in the whole discussion carefully and distinctly marked?

7. Does Professor James's style differ essentially from that of Morgan or of Bryce? After a careful examination of the styles of these three men, give your opinion as to the soundness of the following remarks on the scientific style: "The negative quality of lucidity is the one essential attribute of the scientific writer's style. . . . The writer's expression has the precision if not the soulless mechanism of the instrument he uses in his laboratory or observatory, and is quite as impersonal; the distinctively literary style is not pertinent to it. . . . In science, even when it is concerned with human factors—as in psychology or sociology—the impersonal view is maintained, and the elucidation has an appeal absolutely direct and formal, addressed to the understanding."

Exercise 1. The meaning of a word may be determined by several methods. A very useful method sometimes is by examination of the history and etymology of the word. Try by this method to give an accurate definition of religion.

Exercise 2. Define by one or several of the methods of definition, any one of the following terms:

The American spirit.
The square deal.
The practical politician.
Scholarship.
Heroism.
Faith.
Absolute zero.
An acid.
The idle rich.

THE DISCOVERY OF THE FUTURE[1]

H. G. Wells

It will lead into my subject most conveniently to contrast and separate two divergent types of mind, types which are to be distinguished chiefly by their attitude toward time, and more

[1] A part of a discourse delivered at the Royal Institution on Friday, January 24, 1902. Reprinted from *Nature*, London, Vol. 65, Feb. 6, 1902.

particularly by the relative importance they attach and the relative amount of thought they give to the future of things.

The first of these two types of mind, and it is, I think, the predominant type, the type of the majority of living people, is that which seems scarcely to think of the future at all, which regards it as a sort of black nonexistence upon which the advancing present will presently write events. The second type, which is, I think, a more modern and much less abundant type of mind, thinks constantly and by preference of things to come, and of present things mainly in relation to the results that must arise from them. The former type of mind, when one gets it in its purity, is retrospective in habit, and it interprets the things of the present, and gives value to this and denies it to that, entirely with relation to the past. The latter type of mind is constructive in habit, it interprets the things of the present and gives value to this or that, entirely in relation to things designed or foreseen. While from that former point of view our life is simply to reap the consequences of the past, from this our life is to prepare the future. The former type one might speak of as the legal or submissive type of mind, because the business, the practice, and the training of a lawyer dispose him toward it; he of all men must most constantly refer to the law made, the right established, the precedent set, and most consistently ignore or condemn the thing that is only seeking to establish itself. The latter type of mind I might for contrast call the legislative, creative, organizing, or masterful type, because it is perpetually attacking and altering the established order of things, perpetually falling away from respect for what the past has given us. It sees the world as one great workshop, and the present is no more than material for the future, for the thing that is yet destined to be. It is in the active mood of thought, while the former is in the passive; it is the mind of youth, it is the mind more manifest among the western nations, while the former is the mind of age, the mind of the oriental.

Things have been, says the legal mind, and so we are here. And the creative mind says we are here because things have yet to be.

Now I do not wish to suggest that the great mass of people belong to either of these two types. Indeed, I speak of them as two distinct and distinguishable types mainly for convenience and in order to accentuate their distinction. There are probably very few people who brood constantly upon the past without any thought of the future at all, and there are probably scarcely any who live and think consistently in relation to the future. The great mass of people occupy an intermediate position between these extremes, they pass daily and hourly from the passive mood to the active, they see this thing in relation to its associations and that thing in relation to its consequences, and they do not even suspect that they are using two distinct methods in their minds.

But for all that they are distinct methods, the method of reference to the past and the method of reference to the future, and their mingling in many of our minds no more abolishes their difference than the existence of piebald horses proves that white is black.

I believe that it is not sufficiently recognized just how different in their consequences these two methods are, and just where their difference and where the failure to appreciate their difference takes one. This present time is a period of quite extraordinary uncertainty and indecision upon endless questions—moral questions, æsthetic questions, religious and political questions—upon which we should all of us be happier to feel assured and settled, and a very large amount of this floating uncertainty about these important matters is due to the fact that with most of us these two insufficiently distinguished ways of looking at things are not only present together, but in actual conflict in our minds, in unsuspected conflict; we pass from one to the other heedlessly without any clear recognition of the fundamental difference in conclusions that exists between the two, and we do this with disastrous results to our confidence and to our consistency in dealing with all sorts of things.

But before pointing out how divergent these two types or habits of mind really are, it is necessary to meet a possible objection to what has been said. I may put that objection in

this form: Is not this distinction between a type of mind that thinks of the past and of a type of mind that thinks of the future a sort of hair splitting, almost like distinguishing between people who have left hands and people who have right? Everybody believes that the present is entirely determined by the past you say; but then everybody believes also that the present determines the future. Are we simply separating and contrasting two sides of everybody's opinion? To which one replies that we are not discussing what we know and believe about the relations of past, present, and future, or of the relation of cause and effect to each other in time. We all know the present depends for its causes on the past, and that the future depends for its causes upon the present. But this discussion concerns the way in which we approach things upon this common ground of knowledge and belief. We may all know there is an east and a west, but if some of us always approach and look at things from the west, if some of us always approach and look at things from the east, and if others again wander about with a pretty disregard of direction, looking at things as chance determines, some of us will get to a westward conclusion of this journey, and some of us will get to an eastward conclusion, and some of us will get to no definite conclusion at all about all sorts of important matters. And yet those who are traveling east, and those who are traveling west, and those who are wandering haphazard, may be all upon the same ground of belief and statement and amidst the same assembly of proven facts. Precisely the same thing will happen if you always approach things from the point of view of their causes, or if you approach them always with a view to their probable effects. And in several very important groups of human affairs it is possible to show quite clearly just how widely apart the two methods, pursued each in its purity, take those who follow them.

I suppose that three hundred years ago all people who thought at all about moral questions, about questions of right and wrong, deduced their rules of conduct absolutely and unreservedly from the past, from some dogmatic injunction, some finally settled decree. The great mass of people do so to-day. It is

written, they say. Thou shalt not steal, for example—that is the sole, complete, and sufficient reason why you should not steal, and even to-day there is a strong aversion to admit that there is any relation between the actual consequences of acts and the imperatives of right and wrong. Our lives are to reap the fruits of determinate things, and it is still a fundamental presumption of the established morality that one must do right though the heavens fall. But there are people coming into this world who would refuse to call it right if it brought the heavens about our heads, however authoritative its sources and sanctions, and this new disposition is, I believe, a growing one. I suppose in all ages people in a timid, hesitating, guilty way have tempered the austerity of a dogmatic moral code by small infractions to secure obviously kindly ends, but it was, I am told, the Jesuits who first deliberately sought to qualify the moral interpretation of acts by a consideration of their results. To-day there are few people who have not more or less clearly discovered the future as a more or less important factor in moral considerations. To-day there is a certain small proportion of people who frankly regard morality as a means to an end, as an overriding of immediate and personal considerations out of regard to something to be attained in the future, and who break away altogether from the idea of a code dogmatically established for ever. Most of us are not so definite as that, but most of us are deeply tinged with the spirit of compromise between the past and the future; we profess an unbounded allegiance to the prescriptions of the past, and we practice a general observance of its injunctions, but we qualify to a vague, variable extent with considerations of expediency. We hold, for example, that we must respect our promises. But suppose we find unexpectedly that for one of us to keep a promise, which has been sealed and sworn in the most sacred fashion, must lead to the great suffering of some other human being, must lead, in fact, to practical evil? Would a man do right or wrong if he broke such a promise? The practical decision most modern people would make would be to break the promise. Most would say that they did evil to avoid a greater evil. But suppose it was

not such very great suffering we were going to inflict, but only some suffering? And suppose it was a rather important promise? With most of us it would then come to be a matter of weighing the promise, the thing of the past, against this unexpected bad consequence, the thing of the future. And the smaller the overplus of evil consequences the more most of us would vacillate. But neither of the two types of mind we are contrasting would vacillate at all. The legal type of mind would obey the past unhesitatingly, the creative would unhesitatingly sacrifice it to the future. The legal mind would say, "they who break the law at any point break it altogether," while the creative mind would say, "let the dead past bury its dead." It is convenient to take my illustration from the sphere of promises, but it is in the realm of sexual morality that the two methods are most acutely in conflict.

And I would like to suggest that until you have definitely determined either to obey the real or imaginary imperatives of the past, or to set yourself toward the demands of some ideal of the future, until you have made up your mind to adhere to one or other of these two types of mental action in these matters, you are not even within hope of a sustained consistency in the thought that underlies your acts, that in every issue of principle that comes upon you, you will be entirely at the mercy of the intellectual mood that happens to be ascendant at that particular moment in your mind.

In the sphere of public affairs also these two ways of looking at things work out into equally divergent and incompatible consequences. The legal mind insists upon treaties, constitutions, legitimacies, and charters; the legislative incessantly assails these. Whenever some period of stress sets in, some great conflict between institutions and the forces in things, there comes a sorting between these two types of mind. The legal mind becomes glorified and transfigured in the form of hopeless loyalty, the creative mind inspires revolutions and reconstructions. And particularly is this difference of attitude accentuated in the disputes that arise out of wars. In most modern wars there is no doubt quite traceable on one side or

the other a distinct creative idea, a distinct regard for some future consequence; but the main dispute even in most modern wars and the sole dispute in most mediæval wars will be found to be a reference, not to the future, but to the past; to turn upon a question of fact and right. The wars of Plantagenet and Lancastrian England with France, for example, were based entirely upon a dummy claim, supported by obscure legal arguments, upon the crown of France. And the arguments that center about the present war in South Africa ignore any ideal of a great united South African state almost entirely, and quibble this way and that about who began the fighting and what was or was not written in some obscure revision of a treaty a score of years ago; yet beneath the legal issues the broad creative idea has been very apparent in the public mind during this war. It will be found more or less definitely formulated beneath almost all the great wars of the past century, and a comparison of the wars of the nineteenth century with the wars of the middle ages will show, I think, that in this field also there has been a discovery of the future, an increasing disposition to shift the reference and values from things accomplished to things to come.

Yet though foresight creeps into our politics and a reference to consequence into our morality, it is still the past that dominates our lives. But why? Why are we so bound to it? It is into the future we go, to-morrow is the eventful thing for us. There lies all that remains to be felt by us and our children and all those that are dear to us. Yet we marshal and order men into classes entirely with regard to the past, we draw shame and honor out of the past; against the rights of property, the vested interests, the agreements and establishments of the past the future has no rights. Literature is for the most part history or history at one remove, and what is culture but a mold of interpretation into which new things are thrust, a collection of standards, a sort of bed of King Og, to which all new expressions must be lopped or stretched? Our conveniences, like our thoughts, are all retrospective. We travel on roads so narrow that they suffocate our traffic; we live in uncomfortable, inconvenient,

life-wasting houses out of a love of familiar shapes and familiar customs and a dread of strangeness, all our public affairs are cramped by local boundaries impossibly restricted and small. Our clothing, our habits of speech, our spelling, our weights and measures, our coinage, our religious and political theories, all witness to the binding power of the past upon our minds. Yet we do not serve the past as the Chinese have done. There are degrees. We do not worship our ancestors or prescribe a rigid local costume; we venture to enlarge our stock of knowledge, and we qualify the classics with occasional adventures into original thought. Compared with the Chinese we are distinctly aware of the future. But compared with what we might be the past is all our world.

The reason why the retrospective habit, the legal habit, is so dominant, and always has been so predominant, is of course a perfectly obvious one. We follow the fundamental human principle and take what we can get. All people believe the past is certain, defined, and knowable, and only a few people believe that it is possible to know anything about the future. Man has acquired the habit of going to the past because it was the line of least resistance for his mind. While a certain variable portion of the past is serviceable matter for knowledge in the case of everyone, the future is, to a mind without an imagination trained in scientific habits of thought, nonexistent. All our minds are made of memories. In our memories each of us has something that without any special training whatever will go back into the past and grip firmly and convincingly all sorts of workable facts, sometimes more convincingly than firmly. But the imagination, unless it is strengthened by a very sound training in the laws of causation, wanders like a lost child in the blackness of things to come and returns empty.

Many people believe, therefore, that there can be no sort of certainty about the future. You can know no more about the future, I was recently assured by a friend, than you can know which way a kitten will jump next. And to all who hold that view, who regard the future as a perpetual source of convulsive surprises, as an impenetrable, incurable, perpetual blackness,

it is right and reasonable to derive such values as it is necessary to attach to things from the events that have certainly happened with regard to them. It is our ignorance of the future and our persuasion that that ignorance is absolutely incurable that alone gives the past its enormous predominance in our thoughts. But through the ages, the long unbroken succession of fortune tellers—and they flourish still—witnesses to the perpetually smoldering feeling that after all there may be a better sort of knowledge—a more serviceable sort of knowledge than that we now possess.

On the whole there is something sympathetic for the dupe of the fortune-teller in the spirit of modern science; it is one of the persuasions that come into one's mind, as one assimilates the broad conceptions of science, that the adequacy of causation is universal; that in absolute fact, if not in that little bubble of relative fact, which constitutes the individual life, in absolute fact the future is just as fixed and determinate, just as settled and inevitable, just as possible a matter of knowledge as the past. Our personal memory gives us an impression of the superior reality and trustworthiness of things in the past, as of things that have finally committed themselves and said their say, but the more clearly we master the leading conceptions of science the better we understand that this impression is one of the results of the peculiar conditions of our lives, and not an absolute truth. The man of science comes to believe at last that the events of the year A. D. 4000 are as fixed, settled, and unchangeable as the events of the year 1600. Only about the latter he has some material for belief and about the former practically none. And the question arises how far this absolute ignorance of the future is a fixed and necessary condition of human life, and how far some application of intellectual methods may not attenuate even if it does not absolutely set aside the veil between ourselves and things to come. And I am venturing to suggest to you that along certain lines and with certain qualifications and limitations a working knowledge of things in the future is a possible and practicable thing. And in order to support this suggestion I would call your attention to certain

facts about our knowledge of the past, and more particularly I would insist upon this, that about the past our range of absolute certainty is very limited indeed. About the past I would suggest we are inclined to overestimate our certainty, just as I think we are inclined to underestimate the certainties of the future. And such a knowledge of the past as we have is not all of the same sort or derived from the same sources. Let us consider just what an educated man of to-day knows of the past. First of all he has the realest of all knowledge—the knowledge of his own personal experiences, his memory. Uneducated people believe their memories absolutely, and most educated people believe them with a few reservations. Some of us take up a critical attitude even toward our own memories; we know that they not only sometimes drop things out, but that sometimes a sort of dreaming or a strong suggestion will put things in. But for all that, memory remains vivid and real as no other knowledge can be, and to have seen and heard and felt is to be nearest to absolute conviction. Yet our memory of direct impressions is only the smallest part of what we know. Outside that bright area comes knowledge of a different order—the knowledge brought to us by other people. Outside our immediate personal memory there comes this wider area of facts or quasi facts told us by more or less trustworthy people, told us by word of mouth or by the written word of living and of dead writers. This is the past of report, rumor, tradition, and history—the second sort of knowledge of the past. The nearer knowledge of this sort is abundant and clear and detailed, remoter it becomes vaguer, still more remotely in time and space it dies down to brief, imperfect inscriptions and enigmatical traditions, and at last dies away, so far as the records and traditions of humanity go, into a doubt and darkness as black, just as black, as futurity. And now let me remind you that this second zone of knowledge outside the bright area of what we have felt and witnessed and handled for ourselves—this zone of hearsay and history and tradition—completed the whole knowledge of the past that was accessible to Shakespeare, for example. To these limits man's knowledge of the past was

absolutely confined save for some inklings and guesses, save for some small, almost negligible beginnings, until the nineteenth century began. Besides the correct knowledge in this scheme of hearsay and history a man had a certain amount of legend and error that rounded off the picture in a very satisfying and misleading way, according to Bishop Ussher, just exactly 4004 years B. C. And that was man's universal history—that was his all—until the scientific epoch began. And beyond those limits—? Well, I suppose the educated man of the sixteenth century was as certain of the nonexistence of anything before the creation of the world as he was, and as most of us are still, of the practical nonexistence of the future, or at any rate he was as satisfied of the impossibility of knowledge in the one direction as in the other.

But modern science, that is to say the relentless systematic criticism of phenomena, has in the past hundred years absolutely destroyed the conception of a finitely distant beginning of things; has abolished such limits to the past as a dated creation set, and added an enormous vista to that limited sixteenth century outlook. And what I would insist upon is that this further knowledge is a new kind of knowledge, obtained in a new kind of a way. We know to-day, quite as confidently and in many respects more intimately than we know Sargon or Zenobia or Caractacus, the form and the habits of creatures that no living being has ever met, that no human eye has ever regarded, and the character of scenery that no man has ever seen or can ever possibly see; we picture to ourselves the labyrinthodon raising its clumsy head above the waters of the carboniferous swamps in which he lived, and we figure the pterodactyls, those great bird lizards, flapping their way athwart the forests of the Mesozoic age with exactly the same certainty as that with which we picture the rhinoceros or the vulture. I doubt no more about the facts in this further picture than I do about those in the nearest. I believe in the megatherium which I have never seen as confidently as I believe in the hippopotamus that has engulfed buns from my hand. A vast amount of detail in that further picture is now fixed and

finite for all time. And a countless number of investigators are persistently and confidently enlarging, amplifying, correcting, and pushing further and further back the boundaries of this greater past—this prehuman past—that the scientific criticism of existing phenomena has discovered and restored and brought for the first time into the world of human thought. We have become possessed of a new and once unsuspected history of the world—of which all the history that was known, for example, to Dr. Johnson is only the brief concluding chapter; and even that concluding chapter has been greatly enlarged and corrected by the exploring archæologists working strictly upon the lines of the new method—that is to say, the comparison and criticism of suggestive facts.

I want particularly to insist upon this, that all this outer past—this nonhistorical past—is the product of a new and keener habit of inquiry, and no sort of revelation. It is simply due to a new and more critical way of looking at things. Our knowledge of the geological past, clear and definite as it has become, is of a different and lower order than the knowledge of our memory, and yet of a quite practicable and trustworthy order—a knowledge good enough to go upon; and if one were to speak of the private memory as the personal past, of the next wider area of knowledge as the traditional or historical past, then one might call all that great and inspiring background of remoter geological time the inductive past.

And this great discovery of the inductive past was got, by the discussion and rediscussion and effective criticism of a number of existing facts, odd-shaped lumps of stone, streaks and bandings in quarries and cliffs, anatomical and developmental details that had always been about in the world, that had been lying at the feet of mankind so long as mankind had existed, but that no one had ever dreamed before could supply any information at all, much more reveal such astounding and enlightening vistas. Looked at in a new way they became sources of dazzling and penetrating light. The remoter past lit up and became a picture. Considered as effects, compared

and criticised, they yielded a clairvoyant vision of the history of interminable years.

And now, if it has been possible for men by picking out a number of suggestive and significant looking things in the present, by comparing them, criticising them, and discussing them, with a perpetual insistence upon why? without any guiding tradition, and indeed in the teeth of established beliefs, to construct this amazing searchlight of inference into the remoter past, is it really, after all, such an extravagant and hopeless thing to suggest that, by seeking for operating causes instead of for fossils, and by criticising them as persistently and thoroughly as the geological record has been criticised, it may be possible to throw a searchlight of inference forward instead of backward, and to attain to a knowledge of coming things as clear, as universally convincing, and infinitely more important to mankind than the clear vision of the past that geology has opened to us during the nineteenth century?

QUESTIONS AND EXERCISES

One of the most effectual means of defining is to compare an idea with some other idea closely related. Definition by discrimination, as this method may be called, is illustrated in the foregoing selection.

1. Note the first statement of the contrast between the "legal" and the "creative" types of mind. Show how the distinction is amplified in the first three paragraphs.

2. Does the bringing out of the consequences of these two types of mind in the two spheres of morality and of public affairs help to make clearer the distinction between them?

Exercise 1. Discriminate by a clean-cut and searching contrast one of the following:

Learning and knowledge.
Conventionality and propriety.
Work and exercise.
Comfort and luxury.
News and gossip.
Truth and fact.

Salary and wages.
Charity and alms-giving.
Men of thought and men of action.
Manual training schools and trade schools.
The real farmer and the comic paper farmer.

SCIENTIFIC CLASSIFICATION

TYPES OF MONOPOLIES[1]

Richard T. Ely

As our first step in the discussion of monopolies is the definition of monopoly, so the second step is the classification of monopolies, with an examination of their causes. What we need here as elsewhere in the scientific and popular discussions of economic problems is analysis, for the tendency in discussions of both kinds is to generalize too hastily. The inclination is to say that monopolies are bad, or perhaps sometimes a desire may be discovered to say that on the whole they are good. Analysis, however, may reveal such differences in monopolies that we shall be able to say little if anything applicable to all monopolistic businesses save the simple statement that over them unified control is exercised—in other words, that they are monopolies!

One further preliminary observation suggests itself, namely, that classification of monopolies is not only based upon their causes, but reveals their causes; consequently they may best be discussed together.

The first great separation of monopolies is into main classes, and it has regard to ownership and the direct and immediate beneficiary. The two classes are:

A. Public Monopolies.

B. Private Monopolies.

Public Monopolies are those businesses which are owned and operated by some political unit, and this political unit is the

[1] Reprinted from *Monopolies and Trusts* by permission of the author and the publishers, The Macmillan Company.

direct and immediate beneficiary; in other words, to this political unit in the first place flow all the benefits of the monopoly. *A Private Monopoly, on the other hand, is a monopoly owned and operated by a private person;* it may be a natural person—that is, a human being—or some association of natural persons, as a partnership, or it may be the artificial person called a private corporation. In this case the first and immediate beneficiary of the benefits of the property and business is the private person, although large benefits may flow to the general public.

We may also have *mixed monopolies*, as where a political unit owns monopolistic property which is managed by a private person, or where a private person owns monopolistic property which is managed by a public agency. The former case is illustrated by those railways owned by our commonwealths or cities and operated by private corporations; the latter case finds illustration in privately owned railways operated by the State.

There are private corporations which have what is called a quasi-public character, because the businesses owned and managed by them are of vital importance to society at large, and because society, through government, reserves special rights of regulation over their business operations. When, however, these businesses are monopolies, they fall within the class of private monopolies. They are privately owned, and the benefits of private property flow directly and immediately into private pockets. It is believed that this great fundamental distinction between public and private monopolies is essential both to clear thinking and to sound policy. Whoever undertakes to tell us what is true about monopolies, and what is wise for society to do with respect to monopolies, must make it plain whether he is talking about public monopolies or whether he is discussing private monopolies.

The second classification of monopolies is made with reference to the source of monopoly-power, and is based upon a different principle of classification, so that this second classification will cut across the first. We have again two main classes, and these are:

A. Social Monopolies.

B. Natural Monopolies.

A Social Monopoly is a monopoly which arises out of social arrangement and is an expression of the will of society as a whole, through government, or of a section of society strong enough to impose its will on society. A Natural Monopoly, on the other hand, is a monopoly which rests back on natural arrangements as distinguished from social arrangements.

The term natural here is used in its well-understood and customary sense, to indicate something external to man's mind. A natural monopoly is one which, so far from giving expression to the will of society, grows up apart from man's will and desire, as expressed socially, and frequently in direct opposition to his will and desire thus expressed.

Social monopolies and natural monopolies may be divided into classes and sub-classes, as follows:

A. Social Monopolies

I. General Welfare Monopolies.
   1. Patents.
   2. Copyrights.
   3. Public Consumption Monopolies.
   4. Trade-marks.
   5. Fiscal Monopolies.

II. Special Privilege Monopolies.
   1. Those based on public favoritism.
   2. Those based on private favoritism.

B. Natural Monopolies

I. Those arising from a limited supply of raw material.

II. Those arising from properties inherent in the business.

III. Those arising from secrecy.

With reference to the completeness of the monopoly, we have a classification into:

A. Absolute Monopolies.

By this we mean a complete control over the entire supply

of the article or service. A gas business, in the hands of one corporation, alone furnishing gas to the inhabitants of a given city, affords an illustration.

B. Complete Monopolies.

By a complete monopoly we mean a monopoly which results from substantial unity of action on the part of those in business —what people ordinarily call a monopoly, although there may not be absolute control over the entire business. We might say, perhaps, that the Standard Oil Company is a complete monopoly, but it does not have an absolute monopoly. It is sometimes said that a combination of those furnishing from seventy-five to ninety-five per cent. of the supply of a commodity results in substantial control over price, and thus gives a monopoly. The proportion of supply necessary to establish a monopoly must vary with the circumstance of each particular case. Monopoly, as it is defined in the present work, includes complete monopoly, and a higher form would be absolute monopoly.

C. Partial or Incomplete Monopolies.

Partial monopolies have already been explained in another connection. They exist whenever one or more persons control so large a portion of the field of a particular business that they are able to restrain competition and secure some of the advantages of monopoly; so that the conditions determining price and other conditions are appreciably different from what they would be under free competition.

We may make another classification with reference to the increase in the supply of the monopolized articles:

A. Monopolies which permit no Increase in the Supply of the Monopolized Articles.

An example would be the works of an old master like Raphael. There is no increase of the supply possible.

B. Monopolies permitting an Increased Supply of the Monopolized Articles.

The supply of a monopolized article may frequently be increased by those who control the monopoly. That is the case, for example, with reference to the gas supply.

We may also have at this point a sub-classification with

reference to the conditions under which the supply may be increased:

I. With Increasing Difficulty.

It is alleged that the telephone service in a great city is of this kind, but the author does not know whether it is true or not. It is so claimed by our private companies, but it is unfortunately true that their claim is not sufficient to convince some of us. To find out whether this is true or not, we would have to go to a place where the service is provided by public bodies.

Unless the point of full utilization of an existing plant has been reached, the alleged increasing expenses per unit of increasing business in the case of the telephone must refer to single items, especially those immediately belonging to that department of the service which has to do with establishing connections between the increasing numbers of users of the telephone. Obviously many other expenses do not increase in proportion as the business increases. Manifestly, also, the telephone business of any city can be conducted for less by one plant than by two competing plants, provided that the same ends are even approximately secured; for rivalry implies two telephones for a large proportion of the subscribers; and even if every subscriber had two telephones, the same ends would be only approximately reached, as the absence of unity would be an inconvenience involving considerable annoyance and loss.

Apropos of the salt which must frequently accompany acceptance of the claims of great corporations, it may be remarked that the Western Union Telegraph Company claimed for years that it was impossible to have underground wires, although it was known at the time, and had long been known, that such an arrangement was quite possible.

Another illustration of this sub-class would be the pictures of a great living artist, who had already painted as many as he could easily, but with a certain increasing difficulty might increase the number.

Another possible case would be some choice wines from vineyards in a particular section of the country.

II. With Constant Difficulty.

Possibly, after a certain point is reached, a copyrighted book would be an illustration. Up to that point, the larger the supply the less will be the cost per book. By the time we reach one hundred thousand we have perhaps got as low in price as possible. The publisher, in that case, could not furnish two hundred thousand for less per book than he could one hundred thousand.

III. With Decreasing Difficulty.

The gas business affords an illustration: but the qualifications already mentioned must be borne in mind.

The above classification is one which has especial importance in the discussion of price and of the taxation of monopolies.

A. Local Monopolies.

These are monopolies extending over a relatively small area. The gas supply of any city is an illustration. There are various monopolies which are confined to a single locality. Then there are temporary local monopolies which under peculiar exigencies may arise. Two young men in Chicago last winter cornered the market on eggs and made fifteen thousand dollars out of the operation. The weather was so cold that eggs could not be shipped to the city, and for a few days these speculators had a monopoly, accounts of which appeared in the newspapers.

B. National Monopolies.

C. International or Universal Monopolies.

There have been various attempts to secure universal monopoly, of which the copper monopoly of 1899 affords an illustration.

These are more or less arbitrary divisions, because a protective tariff may enable a monopoly to exist in one country when the same article or service is not monopolized in another country. There are attempts to establish monopolies beyond the nation, but how large will be the number of cases in which success will be achieved remains to be seen. There is no doubt that the oil companies of the United States and Russia are endeavoring to establish an international and even a world-monopoly. The Standard Oil Company has a complete monopoly in this country, in Germany, in England, and in France.

We may have a classification based upon the position which the monopolists hold with reference to sales and purchases. This gives us:

A. Sellers' Monopolies.

B. Buyers' Monopolies.

Buyers' monopolies are less frequent than sellers' monopolies, because the buyers of any commodity or service are so often more numerous than the sellers. There are, however, cases in which buyers have special facilities for establishing monopolies. Wholesale buyers have some facilities, because they are not so large in number as those from whom they purchase. The buyers of labor power, especially, have facilities for establishing a monopoly. Professor Wilhelm Lexis mentions the buyers of second-hand goods. It is hard to see how a second-hand dealer has, in general, anything which can properly be called a monopoly, although, as Professor Lexis says, a man may feel a certain reluctance to sell a second-hand suit of clothes, and this may give the buyer an advantage.

We may also have the following classification with reference to the objects of monopoly:

A. Material Goods.

B. Services.

- I. Services which are incorporated in material goods—what the Germans call "material labor services," *e. g.* the service in the transportation of freight.
- II. Personal services; as those of a physician or nurse. But it is only rarely that a monopoly of this sort exists on a large scale. Where it is found, it is usually in some small town or rural district.

These, then, are the various classifications. Doubtless we could extend the classifications indefinitely from one point of view or another, but the classifications given are sufficient for our purposes. The most important classification, and the most thoroughgoing, is the second one, which is the classification with reference to the sources of monopoly-power.

It will be convenient now to present by themselves, without comment, the classifications of monopolies which the author

offers, before passing on to classifications which other writers have given:

First Classification:
- A. Public Monopolies.
- B. Private Monopolies.

Second Classification:
- A. Social Monopolies.
  - I. General Welfare Monopolies.
    1. Patents.
    2. Copyrights.
    3. Public Consumption Monopolies.
    4. Trade-marks.
    5. Fiscal Monopolies.
  - II. Special Privilege Monopolies.
    1. Those based on Public Favoritism.
    2. Those based on Private Favoritism.
- B. Natural Monopolies.
  - I. Those arising from a limited supply of raw material.
  - II. Those arising from properties inherent in the business.
  - III. Those arising from secrecy.

Third Classification:
- A. Absolute Monopolies.
- B. Complete Monopolies.
- C. Partial or Incomplete Monopolies.

Fourth Classification:
- A. Monopolies which admit of no increase in the supply of the monopolized articles.
- B. Monopolies which admit of an increased supply of the monopolized articles.
  - I. With Increasing Difficulty.
  - II. With Constant Difficulty.
  - III. With Decreasing Difficulty.

Fifth Classification:
- A. Local Monopolies.
- B. National Monopolies.
- C. International or Universal Monopolies.

Sixth Classification:
- A. Sellers' Monopolies.
- B. Buyers' Monopolies.

Seventh Classification:
- A. Monopolies of Material Goods.
- B. Monopolies of Services.
  - I. Services Incorporated in Material Goods.
  - II. Personal Services.

QUESTIONS AND EXERCISES

Complementary to definition, the process of exposition that views an idea in its entirety, is the process of classification that resolves a subject into its constituent parts. Definition and classification usually occur together. For example, while Bryce was obviously principally concerned with definition in the piece "Equality," yet the first part of the selection with its analysis of the content of the term *equality* represents the process of classification. Again, Professor Ely is mainly concerned with classifications of monopolies, but he also finds it useful to give a good deal of definition in connection with them. He states the value of classification when he says near the beginning of the selection that it is a safeguard against hasty and imperfect generalizations. A good classification of the parts of a subject is a mark of mental grasp. Although for ordinary purposes it is neither necessary nor desirable to make classifications as complete and exhaustive as these of Professor Ely, nevertheless it will be very helpful for the student to consider perfect and complete classification as his goal and to observe the rules for logical classification as far as possible.

1. Examine each of the classifications of monopolies here given to see if it is in accord with the principles of logical classification. The following statement of principles is taken nearly verbatim from Genung's *The Working Principles of Rhetoric*, page 570:—1. The principle of classification. By this is meant a certain definite character attributed to the whole field of view, to which all the dividing members are equally related. 2. The members of the classification. By these are meant the several parts or distinctions which add together to make up the whole. Of these it is requisite: first, that no one member cover the whole field of classification—there must be more than one member, otherwise there is no classification at all;

secondly, that all the members together cover the whole field, no more and no less; thirdly, that each member exclude from its particular field each and every other. 3. The completeness of the classification. The requisite that the dividing members taken together shall equal the divided whole gives rise to the chief difficulty, namely, of making sure that all the coördinate distinctions of the case are mentioned. Any distinction left out might, if supplied, invalidate the whole process; hence the necessity of covering the whole field.

2. What purposes do the remarks interspersed with the classifications serve? Would the classifications be clear without them, or are the classifications open to misinterpretation without suitable examples in explanation?

Exercise 1. After the manner of Professor Ely's discussion of monopolies, make a careful and systematic classification of the following occupations: Blacksmithing, farming, stage-driving, medicine, shoe-making, teaching, mining, hair-cutting, watch-making, ice cutting, pleasure seeking by an idle rich person, tramping or begging, quarrying, driving a locomotive, tailoring.

Exercise 2. In various discussions of the essay the following different types have been noted: Scientific essays, narrative essays, conversational essays, literary essays, didactic essays, expository essays, argumentative essays, essays concerning manners and morals, historical essays, familiar essays, critical essays, philosophical essays, descriptive essays, lyrical essays. Make a careful classification of these as if preliminary to a discussion of the essay as a literary form.

Exercise 3. Make two complete classifications according to different principles, of bridges, or of rocks, or of engines, or of colleges.

Exercise 4. Write an essay making a classification of one of the following:

The students in your college.
The recreations and amusements of students.
The news items in a daily paper.
The stories in Hawthorne's "Twice-Told Tales."
Poe's tales.
The travelling public.
The Waverley novels.
Weapons used for defence.
Pumps.
Boilers.
Batteries.
Water-wheels.

IV

DIVISION

THE MIGRATIONS OF THE RACES OF MEN [1]

JAMES BRYCE

WE may now proceed to inquire what have been the main causes to which an outflow or an overflow of population from one region to another is due. Omitting, for the present, the cases of small colonies founded for special purposes, these causes may be reduced to three. They are food, war, and labor. These three correspond in a sort of a rough way to three stages in the progress of mankind, the first belonging especially to his savage and semi-civilized conditions, the second to that in which he organizes himself in political communities, and uses his organization to prey upon or reduce to servitude his weaker neighbors; the third to that wherein industry and commerce have become the ruling factors in his society and wealth the main object of his efforts. The correspondence however is far from exact, because the need of subsistence remains through the combative and industrial periods a potent cause of migration, while the love of war and plunder, active even among savages, is by no means extinct in the mature civilization of to-day.

1. In speaking of food, or rather the want of food, as a cause, we must include several sets of cases. One is that in which sheer hunger, due perhaps to a drought or a hard winter, drives a tribe to move to some new region where the beasts of chase are

[1] Extract from a paper read at the inaugural meeting of the London branch of the Royal Scottish Geographical Society, 1892. Reprinted from the *Scottish Geographical Magazine*, Vol. 8, p. 400, by permission of the author.

more numerous, or the pastures are not exhausted, or a more copious rainfall favors agriculture.[1] Another is that of a tribe increasing so fast that the pre-existing means of subsistence no longer suffice for its wants. And a third is that where, whether or no famine be present to spur its action, a people conceives the desire for life in a richer soil or a more genial climate. To one or other of these cases we may refer nearly all the movements of populations in primitive times, the best known of which are those which brought the Teutonic and Slavonic tribes into the Roman Empire. They had a hard life in northern and eastern Europe; their natural growth exceeded the resources which their pastoral or village area supplied, and when once one or two had begun to press upon their neighbors, the disturbance was felt by each in succession until some, pushed up against the very gates of the Empire, found those gates undefended, entered the tempting countries that lay towards the Mediterranean and the ocean, and drew others on to follow. Of modern instances the most remarkable is the stream of emigration which began to swell out of Ireland after the great famine of 1846–'47, and which has not yet ceased to flow.

Among civilized peoples the same force is felt in a slightly different form. As population increases the competition for the means of livelihood becomes more intense, while at the same time the standard of comfort tends to rise. Hence, those on whom the pressure falls heaviest (if they are not too shiftless to move), and those who have the keenest wish to better their condition, forsake their homes for lands that lie under another sun. It is thus that the Russian peasantry have been steadily moving from the north to the south of European Russia, till they have now occupied the soil down to the very foot of the Caucasus for some 500 miles from the point they had reached a century and a half ago. It is thus that, on a smaller scale, the

[1] A succession of dry seasons, which may merely diminish the harvests of those who inhabit tolerably humid regions, will produce such a famine in the inner parts of a continent like Asia as to force the people to seek some better dwelling-place.

Greek-speaking population of the west coast of Asia Minor is creeping eastward up the river valleys, and beginning to re-colonize the interior of that once prosperous region. It is thus that North America and Australasia have been filled by the overflow of Europe during the last sixty years, for before that time the growth of the United States and of Canada had been mainly a home growth from the small seeds planted two hundred years earlier. That the mere spirit of enterprise, apart from the increase of population, counts for little as a cause of migration, seems to be shown not only by the slight outflow from Europe during last century, but by the fact that France, where the population is practically stationary, sends out no emigrants save a few to Algeria, while the steady movement from Norway and Sweden does little more than relieve the natural growth of the population of those countries. As regards European emigration to America, it is worth noting that during the last thirty years it has been steadily extending, not only eastward toward the inland parts of Europe, but also downward in the scale of civilization, tapping, so to speak, lower and lower strata. Between 1840 and 1850 the flow toward America was chiefly from the British Isles. From 1849 onward, it began to be considerable from Germany also, and very shortly afterward from Scandinavia, reaching a figure of hundreds of thousands from the European continent in each year. From Germany the migratory tendency spread into Bohemia, Moravia, Poland, and the other Slavonic regions of the Austro-Hungarian monarchy, as well as into Italy. To-day the people of the United States, who had welcomed industrious Germans and hardy Scandinavians because both made good citizens, become daily more restive under the ignorant and semi-civilized masses whom Central Europe flings upon her shores. At the other end of the world, the vast emigration from China is partly attributable to the need of food; but to this I shall recur presently when we come to speak of labor.

2. The second of our causes is war. In early times, or among the rude peoples, it is rather to be called plunder, for most of their wars were undertaken less for permanent conquest than

for booty. The invasions of Britain by the English, of Gaul by the Franks, of England and Scotland by the Norsemen and Danes, all began with mere piratical or raiding expeditions, though ending in considerable transfers of population. The same may be said of the conquest of Pegu and Arakan by the Burmese in the last century, and (to a smaller extent) of that southward movement of the wild Chin and Kachin tribes whom our present rulers of Burmah find so troublesome. It was in war raids that the movement of the Bantu races to the southernmost parts of South Africa, where they have so largely displaced the yellowish Hottentot race, seems to have begun. So the conquests of Egypt and Persia by the first successors of the Prophet, so the conquests of Mexico and Peru by the Spaniards, though tinged with religious propagandism, were primarily expeditions in search of plunder. This character, indeed, belongs all through to the Spanish migrations to the New World. Apparently few people went from Spain meaning, like our colonists a century later, to make a living by their own labor from the soil or from commerce, which, indeed, the climate of Central and South America would have rendered a more difficult task. They went to enrich themselves by robbing the natives or by getting the precious metals from the toil of natives in the mines, a form of commercial enterprise whose methods made it scarcely distinguishable from rapine. In modern times the discovery of the precious metals has helped to swell the stream of immigration, as when gold was discovered in California in 1846 and in Australia a little later; but in these instances, though enrichment is the object, rapine is no longer the means. There are, however, other senses in which we may call war a source of movements of races. It was military policy which planted the Saxons in Transylvania and the French in Lower Canada, and the Scotch and English settlers in the lower and more fertile parts of Ulster; it is military policy which has settled Russian colonies, sometimes armed, sometimes of agricultural dissenters, along the Trans-caucasian frontiers and on the farther shore of the Caspian. It was military policy which led Shalmaneser and Nebuchadnezzar to carry off large parts

of the people of Israel and Judah to settle them in the cities of the Medes or by the waters of Babylon.[1]

As regards the more regular conquests made by civilized states in modern times, such as those of Finland, Poland, Transcaucasia, and Transcaspia by Russia, of Bosnia and Herzegovina by Austria, of India and Cape Colony by Great Britain, of Cochin China and Annam by France, it may be said that they seldom result in any considerable transfer of population. Such effects as they have are rather due to that process of Permeation which we have already considered.

3. Labor (*i. e.*, the need for labor) becomes a potent cause of migrations in this way—that the necessity for having in particular parts of the world men who can undertake a given kind of toil under given climatic conditions draws such men to those countries from their previous dwelling place. This set of cases differs from the cases of migrations in search of subsistence, because the migrating population may have been tolerably well off at home. As the food migrations have been described as an outflow from countries overstocked with inhabitants, so in these cases of labor migration what we remark is the inflow of masses of men to fill a vacuum—that is, to supply the absence in the country to which they move of the sort of workpeople it requires. However, it often happens that the two phenomena coincide, the vacuum in one country helping to determine the direction of the influx from those other countries whose population is already superabundant. This has happened in the case of the most remarkable of such recent overflows, that of the Chinese over the coasts and islands of the Pacific. The need of Western America for cheap labor to make railways and to cultivate large areas just brought under tillage, as well as to supply domestic service, drew the Chinese to California and Oregon, and but for the stringent prohibitions of recent legislation would have brought many thousands of them into the Mississippi Valley. Similar conditions were drawing them in great num-

[1] So the Siamese, after their conquest of Tenasserim, carried off many of the Talain population and settled them near Bangkok, where they remain as a distinct population to this day.

bers to Australia, and especially to North Queensland, whose climate is too hot for whites to work in the fields; but here, also, the influx has been stopped by law. Ten or twelve years ago they were beginning to form so considerable a proportion of the population of the Hawaiian Isles that public opinion there compelled the sugar-planters to cease importing them, and, in order to balance them, Portuguese labor was brought from the Azores, and Japanese from Japan. Into Siam and the Malay Peninsula, and over the Eastern Archipelago, Chinese migration goes on steadily; and it seems not improbable that in time this element may be the prevailing one in the whole of the Indo-China and the adjoining islands, for the Chinese are not only a more prolific but altogether a stronger and hardier stock than either their relatives the Shans, Burmese, and Annamese, or their less immediate neighbors the Malays. If in the distant future there comes to be a time in which the weaker races having been trodden down or absorbed by the more vigorous, few are left to strive for the mastery of the world, the Chinese will be one of those few. None has a greater tenacity of life.

Not unlike these Chinese migrations, but on a smaller scale, is that of Santhals to Assam, and of South Indian coolies to Ceylon (where the native population was comparatively indolent), and latterly to the isles and coasts of the Caribbean Sea. Here there has been a deliberate importation of laborers by those who needed their labor; and, although the laborers have intended to return home after a few years' service, and are indeed under British regulations, supplied with return passage tickets, permanent settlements are likely to result, for the planters of Guiana, for instance, have little prospect of supplying themselves in any other way with the means of working their estates. The coolies would doubtless be brought to tropical Australia also, but for the dislike of the colonists to the regulations insisted on by the Indian Government; so instead of them we see that importation of Pacific islanders into North Queensland which is now a matter of so much controversy. Under very different conditions we find the more spontaneous

immigration of French Canadians into the northern United States, where they obtain employment in the factories, and are now becoming permanently resident. At first they came only to work till they had earned something wherewith to live better at home; but it constantly happens that such temporary migration is the prelude to permanent occupation. So the Irish reapers used to come to England and Scotland before the migration from Ireland to the English and Scottish towns swelled to great proportions in 1847. The Italians who now go to the Argentine Republic less frequently return than did their predecessors of twenty years ago.

In all these instances the transfer of population due to a demand for labor has been, or at least has purported to be, a voluntary transfer. But by far the largest of all such transfers, now happily at an end, was involuntary—I mean that of Africans carried to America to cultivate the soil there for the benefit of white proprietors.[1] From early in the sixteenth century, when the destruction of the native Indians by their Spanish taskmasters in the Antilles started the slave trade,[2] down to our own times, when slavers still occasionally landed their cargoes in Brazil, the number of negroes carried from Africa to America must be reckoned by many millions. In 1791 it was estimated that 60,000 were carried annually to the West Indies alone.

[1] I do not dwell on the slave trade in ancient times, because we have no trustworthy data as to its extent; but there can be no doubt that vast numbers of barbarians from the west, north, and east of Italy and Greece were brought in during five or six centuries, and they must have sensibly changed the character of the population of the countries round the Adriatic and Ægean. Here of course there was no question of climate, but slaves were caught because their captors did not wish to work themselves. The slave trade practiced by the merchants of Bristol before the Norman Conquest and that practiced by the Turkoman, recently, resemble these ancient forms of the practice.

[2] The first negroes were brought from Morocco to Portugal in 1442, soon after which they began to be brought in large numbers from the Guinea coasts. There were already some in Hispaniola in 1502; and after 1517 the trade from Africa seems to have set in regularly, though it did not become large till a still later date. Las Casas lived to bitterly repent the qualified approval he had given to it, in the interests of the aborigines of the Antilles, whom labor in the mines was swiftly destroying; but it is a complete error to ascribe its origin to him.

The change effected may be measured by the fact that along the southern coasts of North America, in the West India islands, and in some districts of Brazil the negroes form the largest part of the population. Their total number, which in the United States alone exceeds 7,000,000, can not be less than from 13,000,000 to 16,000,000. They increase rapidly in South Carolina and the Gulf States of the Union, are stationary in Mexico and Peru, and in Central America seem to diminish. Though some have suggested their re-migration to Africa, there is not the slightest reason to think that this will take place to any appreciable extent. On the other hand, it is not likely that they will, except, perhaps, in the unsettled tropical interior of the less elevated parts of South America, spread beyond the area which they now occupy. The slave trade is unfortunately not yet extinct on the east coast of Africa, but it has caused so comparatively slight a transfer of population from that continent to Arabia, the Turkish dominions, and Persia as not to require discussion here.

Before quitting this part of the subject a passing reference may be made to two other causes of migration, which, though their effects have been comparatively small, are not without interest—religion and the love of freedom. Religion has operated in two ways. Sometimes it has led to the removal of persons of a particular faith, as in the case of the expulsion of the Jews from Spain by Ferdinand and Isabella, the Catholic, an event which affected not only Spain but Europe generally, by sending many capable Spanish Jews to Holland and others to the Turkish East. Similar motives led Philip III to expel the Moriscoes in A. D. 1609. The present Jewish emigration from Russia is also partially, though only partially, traceable to this cause. In another class of cases religion has been one of the motive forces in prompting war and conquest, as when the Arabs overthrew the dominions of the Sassanid kings, overran the eastern part of the East Roman Empire, subjugated North Africa and Spain; and also in the case of the Spanish conquests in America, where the missionary spirit went hand in hand with, and was not felt to be incompatible with, the greed

of gold and the harshest means of satisfying it. The latest American instance may be found in the occupation and government of Paraguay by the Jesuits. Finally, we sometimes find religious feeling the cause of peaceful emigrations. The case which has proved of most historical significance is that of the Puritan settlement in Massachusetts and Connecticut; among those of less note may be reckoned the flight of the Persian fire worshippers to Western India; the Huguenot settlements in Brazil and on the southeastern coast of North America, destroyed soon after their foundation by the Portuguese and Spaniards, and the later flight of the French Protestants after the revocation of the edict of Nantes; the emigration of the Ulster Presbyterians to the United States in last century; the foundation of various German colonies at Tiflis and other places in the Russian dominions.[1] Nor ought we to forget one striking instance of expatriation for the sake of freedom—that of the petty chieftains of Western Norway, who settled Iceland in the ninth century to escape the growing power of King Harold the Fairhaired.

From this political side of our subject we turn to its physical aspects in considering the lines which migration has tended to follow. These have usually been the lines of least resistance, *i. e.*, those in which the fewest natural obstacles in the way of mountains, deserts, seas, and dense forests have had to be encountered. The march of warlike tribes in early times and the movements of groups of emigrants by land in modern times have generally been along river valleys and across the lowest and easiest passes in mountain ranges. The valley of the lower Danube has for this reason, from the fourth century to the tenth, an immense historical importance, for it was along its levels that the Huns, Avars, and Magyars, besides several of the Slavonic tribes, moved in to occupy the countries between the Adriatic and the Theiss. While the impassable barrier of the

[1] The Tiflis Germans left Würtemberg in order to avoid the use of an obnoxious hymn book. The Mennonites went to Southern Russia to escape military service, but the promise made to them by Catherine II has recently been broken, and they have lately been departing to America lest they should be compelled to serve in the Russian army.

Himalaya has at all times prevented any movements of population from Tibet and Eastern Turkistan, the passes to the west of the Indus, and especially the Khaiber and the Bolan, have given access to many invading or immigrating masses, from the days of the primitive Aryans to those of Ahmed Shah Durani in last century. So in Europe, the Alpine passes have had much to do with directing the course of streams of invaders to Italy. So in North America, while the northern line of settlement was indicated by the valley of St. Lawrence and the Great Lakes, the chief among the more southerly lines was that from Virginia into Tennessee and Kentucky over the Cumberland Gap, long the only practicable route across the middle Alleghanies.

Of migrations by sea it has already been remarked that owing to improvements in navigation, they have now become practically independent of distance or any other obstacle. In earlier times also they played a considerable part, but only in the case of such seafaring peoples as the Phenicians, the Greeks, and the Northmen,—instances in which the number of persons transferred must have been comparatively small, though the historical results were profound. Those which most nearly approach the character of national movements were the transfer of a vigorous Phenician shoot to Carthage, of a mass of Greeks to South Italy and Sicily, and of the Jutes, Saxons, and Angles to Britain.

The most important physical factor in determining lines of movement has, however, been climate. Speaking broadly, migration follows the parallels of latitude, or more precisely, the lines of equal mean temperature, and not so much, I think, of mean annual heat as of mean winter heat. Although the inhabitants of cold climates often evince a desire to move into warmer ones, they seem never to transfer themselves directly to one differing greatly from that to which they are accustomed; while no people of the tropics has ever, so far as I know, settled in any part of the temperate zone. There is one instance of a north European race establishing itself on the southern shores of the Mediterranean—the Vandals in North Africa; and the Bulgarians came to the banks of the lower Danube from the

still sterner winters of the middle Volga. But in the few cases of northward movement, as in that of the Lapps, the cause lies in the irresistible pressure of stronger neighbors; and probably a similar pressure drove the Fuegians into their inhospitable isle.

The tendency to retain similar climatic conditions is illustrated by the colonization of North America. The Spaniards and Portuguese took the tropical and sub-tropical regions, neglecting the cooler parts. The French and the English settled in the temperate zone; and it was not till this century that the country toward the Gulf of Mexico began to be occupied by incomers from the Carolinas and northern Georgia. When the Scandinavian immigration began, it flowed to the northwest, and has filled the States of Wisconsin, Minnesota, and Dakota. And when the Icelanders sought homes in the New World, they chose the northernmost place they could find by the shores of Lake Winnipeg, in Manitoba. So the internal movements of population within the United States have been along the parallels of latitude. The men of New England have gone west into New York, Ohio, and Michigan, whence their children have gone still farther west to Illinois, Iowa, Oregon, and Washington. Similarly the overflow of Virginia poured into Kentucky and Tennessee, and thence into southern Illinois and Missouri; while it is chiefly from the Carolinas that Georgia, Alabama, Mississippi, Arkansas, and Texas have been settled. The present negro emigration from the eastern States of the South is into Arkansas and Texas. Oregon is the only Northern State that has received any considerable number of immigrants from the old slave States; and Western Oregon enjoys, in respect of its maritime position, an equable climate, with winters milder than those of Missouri.

QUESTIONS AND EXERCISES

This selection calls attention to the distinction between exact, scientific classification and the mere division of material. Classification is made in the interest of completeness and must therefore be exhaustive. It is worthless unless the separate members of the classification make up the whole idea. Division, on the other hand,

seeks, not exhaustiveness, but merely the conveniences of present treatment and the assistance of the reader's memory. A collection of miscellaneous facts takes on new meaning when we see them so grouped as to bring out certain general principles behind them.

1. How nearly to a complete scientific division or classification has the writer come? Do you find an expressed or implied disavowal of complete classification? Would more than three groups tend to be confusing to the reader?

2. Are the instances and examples in each group intended to be a complete list of the migrations from that particular cause, or are just enough given to fix that cause in the reader's mind? Are the examples drawn from instances familiar enough to belong to the average man's knowledge of history?

Exercise 1. Write a composition of about 500 words on the causes which have led, and are leading to migrations from the country to the towns.

Exercise 2. Write a composition of about 500 words upon one of the following subjects, making a careful division of your material after the manner of Bryce.

Causes of wars.
Forces that produced the Renaissance.
Influence of the invention of printing.
How climate influences occupations and character.
How geographical conditions affect war and commerce.
Evils of labor-saving machinery.
Causes of the French Revolution.

HISTORY OF THE ENGLISH NAMES OF AMERICAN BIRDS[1]

SPENCER TROTTER

TECHNICAL nomenclature is the embodiment of that orderly and definite arrangement of knowledge which constitutes a

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science. It serves to symbolize a conception of the relationships that exist between living beings, one with another, and is at once the expression of a logical system of classification; a working basis for the ideal scheme which the mind constructs from observed facts. It is eminently a rational process. In direct contrast to this is the vernacular—the loose, quite indefinite, and often haphazard way of naming things, that has its root in the soil of common life. The stratum out of which it springs is emotional rather than rational. In ornithology these two contrasted forms of the embodied ideal—the technical or scientific and the vernacular names—have been of more equal value than in many other branches of natural history, from the fact that birds have always presented themselves to men's minds in a peculiarly attractive way. Most of us think of the various kinds of birds, certainly of the more familiar ones, in terms of the vernacular rather than in the garb of science. A song sparrow is a song sparrow more often than a *Melospiza melodia* as well to the ornithologist as to the untechnical wayfarer.

A respectable antiquity attaches itself to the vernacular. Long before the scientific mind had invaded the field of natural history the folk had given voice to its ideas about various animate and inanimate things. A vast vocabulary of popular names was an early heritage of the common people. With this stock of names and notions about Old World birds the colonists in Virginia and New England were fairly well equipped, and the more familiar birds of the new country soon received names indicative of some trait or likeness to certain of the Old World varieties. Mark Catesby in his History of Carolina was the first one to give any substantial account of American birds, and his work contains an array of names, some of them more or less familiar in the speech of to-day. To William Bartram we owe a large number of our common bird names, names that reached the intellectual world of eighteenth century England through the works of Edwards, Pennant, and Latham. Alexander Wilson was likewise a large debtor to Bartram for the names of numerous species, but he blazed his own trail by applying

names to species discovered by himself as well as in the recasting of many Bartramian names.

In the present inquiry I have arranged the matter of the history of our American bird names under the following six heads:

I. Names of old English origin applied to American birds.
II. Names derived from a Latin equivalent.
III. Names suggested by voice.
IV. Names suggested by some peculiar habit or habitat.
V. Names suggested by color or other external feature.
VI. Names suggested by geographical locality (place names) or in honor of some person.

I. NAMES OF OLD ENGLISH ORIGIN

Many of the Catesbian names of birds undoubtedly originated in the vernacular of the colonists and some are clearly of old English ancestry. In the main they are of generic rather than of specific application, as is the case with most of the folk terms for natural objects. The specific distinction is often one of locality merely, as, for example, "the cuckow of Carolina." Relationship is often broadly recognized by the people and embodied in a general name with appropriate qualifications to indicate minor differences or differences in distribution. The "species" of the *profanum vulgus*, however, more nearly corresponds to the generic conception of the naturalist, even in some cases to the idea embodied in the term "family."

A number of these Old World bird names, given to American birds, appear very early in the history of English speech. In a vocabulary compiled by Archbishop Ælfric toward the close of the tenth century (955-1020 A. D.) there is a *Nomina Avium* in which a number of bird names appear, though somewhat different from their modern form. In this list the robin redbreast is called "rudduc" or "ruddock," which long continued to be its general English name and is probably still alive in local dialects. The word appears as a variant of the modern "ruddy," referring no doubt to the russet of the bird's breast. The earliest recorded instance of the use of the popular epithet,

"robin," which as a word of endearment has been transferred to many different birds throughout the English-speaking world, occurs in the *Nomina Avium* of an English vocabulary of the fifteenth century, where the name appears as "robynet redbreast," literally "little robin redbreast." Our American robin was known to the early southern colonists as the "fieldfare," and is so termed by Catesby. The bird has many of the qualities of the fieldfare, and, like its British congener, came from the north in autumn, scattering over the cleared lands in loose flocks. William Bartram speaks of it as the "fieldfare or robin redbreast," and Kalm mentions it under the latter name. Our familiar name "robin" is thus a contraction of the "robin redbreast" of old English speech.

In the *Nomina Avium* of Ælfric the cuckoo occurs as "geac." In some provincial dialects it is still called a "gowk," a survival of the little-altered Anglo-Saxon name. "Cuckoo" or "cuckow" (the latter an earlier form of the name and given as such by Catesby) is undoubtedly derived through later Norman speech (French *coucou;* Italian *cucco* or *cuculo;* old English *cuccu*). The German name *kuckuk* or *koekoek*, the Danish *kukker* or *gjog*, and the Swedish *gok* are clearly allied to the Anglo-Saxon *geac* or *gowk*, all being undoubted variants expressive of the bird's voice, and the same is true of "cuckoo" and its variants.[1] The colonists were not deceived in giving to the American species its rightful name, though Catesby may have been the first to bestow it.

"Crow" appears in Ælfric's vocabulary as *crawe;* "kite" as *glida* and *glede*, the last name continuing down to the fifteenth century. The Anglo-Saxon *staern* or *staer* (later *stare*) has become the modern "starling."

A manuscript in the Royal Library at Brussels, of eleventh century date, contains a number of bird names, among which are the *goshafoc* (literally "goose hawk") modernized to "goshawk," and *spear-hafoc* ("sparrow hawk"). It seems curious that our little American sparrow hawk has not borne the name

[1] To call a man a "gawk" (simpleton) appears equivalent to calling him a "cuckoo," a term of no uncertain meaning in the old days.

of its near relative, the kestral, rather than that of the quite different sparrow hawk of the Old World. "Turtle" was an old name for the dove and appears as such in Catesby. It originated, as Skeat observes, from an effort to express the cooing note and is altogether different from the word used to designate the reptile of the same name. This last was rendered by English sailors into "turtle" from the Spanish *tortuga*.

Wren, sparrow, and swallow appear in these old vocabularies as *wraenna*, *spearwa*, and *swealewe*. The first of these names Skeat asserts is derived from a base *wrin*, to squeal, chirp, or whine, in allusion to the bird's voice. A curious old belief existed among the folk of several European countries that the wren was the "king of birds." Hence, probably the generic term *Regulus* formerly applied to various species of wren, and, likewise, its English equivalent "kinglet." "Sparrow" is literally a "flutterer" (*spar*, to quiver), and "swallow" means a "tosser, or mover to and fro; from its flight" (Skeat). "Lark" has been softened down from the old English "laverok" or "laverock" (Anglo-Saxon *laverce*), literally "a worker of guile," from some old superstition regarding the bird as of ill omen. The bestowal of this name upon an American bird allied to the starlings was no doubt due to an effort on the part of the early settlers to name birds after the more familiar ones of the homeland. The ground-nesting habits, the long hind claw, the loud twittering flight notes and clear song of the American bird may have given some slight reason for this incongruous title.

"Thrush" with its variants "throstle" and "throstle-kok," as applied to the song thrush of Europe, is an old word and appears in its older forms in a treatise by Walter de Biblesworth at the end of the thirteenth century. In the Brussels Manuscript "throstle" seems to refer to the missel thrush. The song thrush is also referred to by its other old English name of "maviz" (later "mavis"). In this same treatise of de Biblesworth's the European blackbird is spoken of as "osel" or "hosel-brit," and likewise by its old English name of "merle." Later it became "ousel-cock" as in the quaint ditty in "Midsummer-Night's Dream"—

The ousel-cock, so black of hue,
  With orange-tawny bill,
The throstle with his note so true,
  The wren with little quill.
The finch, the sparrow, and the lark.
  The plain-song cuckoo gray,
Whose note full many a man doth mark,
  And dares not answer, nay; . . .

"Mawys" or "mavis" as a dialectic name has lasted down to the present day in the counties of east England. It seems curious that it was not transferred to any American thrush, notably the wood thrush. "Osel" is clearly the parent word of the modern "ousel" and in this latter form is still applied to an allied species of the European blackbird—the ring-ousel, as well as to a distinct, though related, family—the dippers or water ousels.

Without doubt the word "thrasher," applied to the birds of the American genus *Toxostoma*, is a variant of "thrush" and "throstle," for we find "thrushel" and "thrusher" as variants in the provincial English dialects. The term "thrasher" occurs in Barton's Fragments (1799), and Wilson also uses the name as a vernacular in his account of the brown thrush or "ferruginous thrush" as he calls it, both of which facts are clear evidence as to the early current use of this common name for the species in question. Catesby figures the bird under the title "fox-colored thrush." In the South it is known here and there as the "sandy mocker" and formerly as the "French mockingbird," this last from the fact that its song was considered inferior to that of the true mockingbird—all things French being regarded with a certain contempt by the English colonists. There is a curious suggestion of the throstle's song in the song of our brown thrasher, a fact also noted by Wilson, and this may have given rise to the current vernacular name.

In a metrical vocabulary, supposedly of the fourteenth century, "sparrow" appears in its modern form; likewise "larke," "pye" (the magpie, "mag" being a contraction of "magot" or "madge," a feminine name formerly bestowed

upon this bird), "revyn" (raven), "parthryd," and "quale." "Jay" also appears in its present day spelling and with its Latin equivalent *Graculusque*, which may be the origin of our modern word "grackle." "Jay" is from old French "gai" equivalent to "gay" (plumage).

In a *Nominale*, or list of words, of fifteenth century date we find "wagsterd" (wagtail), "nuthage" (nuthatch), and "buntyle" (bunting). In a curious pictorial vocabulary, also of the fifteenth century, "kingfisher" appears as "kynges-fychere" and "woodpecker" as "wodake" or "woodhock." Our "redstart" evidently received its name by suggestion from a very different bird of the Old World. It is so called by Catesby. "Start" is from Anglo-Saxon "steort," a tail. "Titmouse" has been transferred to various American species of the family (Catesby figures the "crested titmouse"), the prefix "tit" meaning small. "Mouse" is from Anglo-Saxon *máse*, a name, according to Skeat, for several kinds of small birds, and not to be confounded with the mammal of the same name. Hence, the plural "titmouses," not "titmice," is the proper form, though usage has established it otherwise. "Shrike" is another name transferred from European to allied American species. The name probably had its origin in the voice of this bird or of some thrush, and later bestowed upon the members of the Laniidæ. "Martin" (and its older form "Martlet") was evidently a nickname applied to a European swallow and given by the colonists to our species of the genus *Progne*. Bartram calls the bird "the great purple martin."

"Blackbird," applied to certain American species of Icteridæ, is a name suggested purely by color. Catesby early gave to our *Agelaius phœniceus* its more nearly correct title of "Red-wing'd starling." Kalm uses the older form "stare," and likewise refers to the species of *Quiscalus* as "blackbirds," remarking that "The English call them *blackbirds*." Our goldfinch appears first in Catesby as "The American goldfinch," the name clearly borrowed from the Old World *Carduelis elegans*. "Siskin" in like manner comes from the Old World, the word being originally of Scandinavian origin and meaning "chirper" or "piper."

"Snow bunting" is the old name of *Plectrophenax nivalis* and should rightly replace the fanciful "snowflake." Our "tree sparrow" is the result of a confusion of the American species with the mountain or tree sparrow of Europe. This was corrected by Pennant, but the name "tree" was retained.

A rather curious case of name transfer is that of our yellow-breasted chat. The bird first appears under this title in Catesby's work, and was evidently so called by him in a mistaken idea that it was related to the birds of the same name belonging to the European genus *Saxicola*. This fact is made evident by the Latin word *œnanthe* used in the descriptive designation.

The name "buzzard" as applied to the turkey vulture appears early in the literature of American birds. Catesby calls it "turkey buzzard." As an old English name of Norman French derivation (*Busard*, Latin *Buteo*), it had, as Newton points out, a definite meaning in relation to the old sport of "hawking." Birds of the genera *Buteo* and *Circus* (Harrier) were styled "buzzards" (more especially the species of the former genus), of slow and heavy flight, and "were regarded with infinite scorn, and hence in common English to call a man a buzzard is to denounce him as stupid." With the exception of eagles and owls and a few kites all birds of prey in this country are termed "hawks," and "buzzard" has been relegated to this slow-moving, carrion-feeding species.

II. NAMES DERIVED FROM A LATIN EQUIVALENT

Several of our English bird names have come into every day speech by the anglicizing of their generic titles. The Linnæan genus *Oriolus* (from "Oriole," Latin *aurum*, *gold*) included certain species of Icteridæ, which though very different from the European *Oriolus galbula*, still bear its name. "Junco" and "Vireo" are anglicized generic names. The word "grackle" applied to certain species of our Icteridæ appears to be an anglicized word derived from the Linnæan genus *Gracula*. The word originally referred to the daw or jackdaw of Europe and the relationship between the American birds and the European species, though somewhat distant, was recognized

by early writers. *Quiscalus quiscula* appears in Catesby as "The purple jackdaw." Bartram calls it the "Lesser purple jackdaw or crow blackbird" (the first notice I have found of this last common name). Wilson calls it the "purple grackle," from which source it has without doubt spread into the current vernacular of ornithology, though not into the speech of the people at large.

The name "parula" recently in vogue for the warblers of the genus *Compsothlypis* is clearly borrowed from the old Bonaparte genus *Parula* (diminutive of titmouse). The bird (*C. americana*) has appeared under various titles—"the finch creeper" of Catesby, "the various-colored little finch creeper" of Bartram, and the "blue yellow-backed warbler" of Wilson, Audubon, and later authors.

In "Kinglet" we have a word rendered into English from the generic name *Regulus* (Cuvier), though its use is somewhat recent, "wren" being the vernacular designation of the species of *Regulus* until a comparatively late period. Edwards refers to the species as "Le Roitelet" (also Buffon).

"Tanager" is another derived word from the Linnæan genus *Tanagra*, probably of Brazilian origin.

III. NAMES SUGGESTED BY VOICE

In this group, and in the ones that follow, the vernacular names are more specific in their nature, indicative of some peculiar feature or habit of a species. Bird voices have been embodied from the earliest times in various expressive syllables which have given rise to a variety of names. "Cuckoo" was one of these, and in like manner "wren," "crow," and other bird names of the Old World. The babble of our voluble chat, as we have seen, undoubtedly led Catesby to ally the bird with a group of very different species. In America the colonists soon found names by which to designate a number of birds from peculiarities in their vocal performances. Latham speaks of the "Phœbe-bird," unquestionably given him by some trans-Atlantic correspondent. Our name "pewee" is given "pewit" by Bartram. Wilson named the "wood pewee" from its voice and its habitat.

The older writers give "rice bird" as the chief caption of *Dolichonyx oxyzivorus* and Bartram calls the male "the pied rice bird." Wilson calls it "rice bird," but mentions its other names, "boblink" and "reed bird." Nuttall, as a good New Englander, gives "bob-o-link" as its principal name, and Barton, in his Fragments, has "bob-lincoln." I find this last title also in a sketch of the English writer, William Hazlitt (1785). These are the earliest references I can find to this song name of the bird which appears to have been early in use throughout New York and New England.

Among the current specific appellations of certain sparrows some recent changes are noteworthy.

The "yellow winged sparrow" of Wilson is now the "grasshopper sparrow," the first allusion to its grasshopper-like notes being, as far as I can find, in Coues's Birds of the Northwest (p. 133). We owe the attractive name of "vesper sparrow" to John Burroughs (Wake Robin), which has superseded the older "grass finch" of Pennant and Gmelin and the "bay-winged finch" of Wilson. The "chipping sparrow" is through Wilson from the earlier "little house sparrow or chipping bird" of Bartram. "Song sparrow" unquestionably originated through Wilson, as also the specific title *melodia*. Catesby figures and describes "the towhe-bird" (*Pipilo erythrophthalmus*). Wilson speaks of its name in Pennsylvania as "chewink." "Towhee" is a later form of the word by adding an additional "e." "Swamp robin" and (in Virginia) "bullfinch" are other names mentioned by Wilson.

"Pipit" is an old English name applied to the titlarks, and is derived through "peep" from "pipe," imitative of the bird's note.

Catesby calls the mockingbird "The mock bird," though Bartram gives it its modern form. "Catbird" appears as such in Catesby, and Bartram adds "chicken bird" as a synonym. "Chickadee" as a general imitative vernacular name for the species of *Parus* I find first in Audubon. The name "veery," given to the tawny thrush in imitation of its note, is first used as a synonym by Nuttall.

"Warbler," as a general term for small song birds of the Old World family Sylviidæ, has come down from a word in several of the old European tongues (Old French, Old High German, Middle English—*Werbler*, *Werbelen*), meaning to whirl, run around, warble, as a bird (Skeat). In its special application to the species of *Sylvia*, which we owe to Pennant (1773), it included the American warblers which were later separated as a distinct family under the title of "wood warblers." "Wood warbler," however, has not prevailed, and "warbler" continues to be the current vernacular for the various species of this characteristic American family, though, as we are well aware, the name belies the insect-like notes, drawling monotones, lispings, and wheezing performances of the majority of the species. A few do really warble in the accepted sense of the term, but most speak in a tongue peculiarly their own.

Kalm speaks of "whip-poor-will" as the English name of *Antrostomus vociferus*. A confusion appears in Bartram, who has it "night hawk or whip-poor-will." *Antrostomus carolinensis* is called by Bartram "the great bat, or chuck wills widow." "Night hawk" is given by Wilson, though this species appears to have been described by Catesby under the name of "the goatsucker of Carolina."

Colinus virginianus has long proclaimed his proper title of "bob-white," which has now become the accepted name of the species, superseding the older and less distinctive terms of "quail" and "partridge."

IV. NAMES SUGGESTED BY SOME PECULIAR HABIT OR HABITAT

"Flycatcher" is a name of obvious application given to an Old World group of birds. From the peculiar habits of certain American species the term "tyrant flycatchers" has become current. The "kingbird" is first so called by Bartram. Catesby figures the species as "the tyrant," whence the name of general application. Wilson speaks of its name in Maryland as the "field martin," and "bee martin" is another name in certain localities.

"Gnatcatcher" is a name that first appears in Audubon,

from the Swainsonian genus *Culicivora*. The species was originally "the little bluish gray wren" of Bartram, and later the "small blue gray flycatcher" of Wilson.

Several species of warblers early received names indicative of peculiar habits. The worm-eating warbler of Wilson and later authors was originally "the worm-eater" (Edwards, Gleanings), from Bartram; also Latham and Pennant from the same source. The pine-creeping warbler of Wilson was the "pine creeper" of Catesby. Edwards, quoting a letter from Bartram, says of *Seiurus aurocapillus* that it "builds its nest upon the ground, and always chooses the south side of a hill; that it makes a hole in the leaves, like a little oven, and lines it with dry grass," etc. This is the first reference I have found of the familiar vernacular "ovenbird," although Edwards calls the species "golden-crowned thrush." "Water thrush" and "wagtail" were names early given to the other species of the genus, and Pennant speaks of one as the "New York warbler," whence its old specific name of *noveboracensis*. The vernacular "myrtle bird" first appears in Nuttall, hence probably "myrtle warbler" of authors, though early accounts speak of the bird's fondness for the berries of the wax myrtle. Catesby calls it "the yellow-rump" and Edwards "the golden-crowned flycatcher." The magnolia warbler was found by Wilson "among the magnolias, not far from Fort Adams, on the Mississippi." He called it the "black and yellow warbler, *Sylvia Magnolia*," hence "magnolia warbler" of later authors. *Dendroica palmarum*, the "palm warbler" of Latham, is the "yellow red pole" of Edwards (*Parus aureus vertice rubio* of Bartram) and the "yellow red-poll warbler" of Wilson. Wilson called *Dendroica discolor* the "prairie warbler" from the open tracts of Kentucky where he first found it.

Of the sparrows, several species have received names indicative of habitat. The "little field sparrow" of Bartram became the "field sparrow" of Wilson and later authors ("bush sparrow" of Burroughs). Wilson first bestowed the vernacular title of "swamp sparrow" upon *Melospiza georgiana*, though it was known to Bartram as "the reed sparrow." In like manner

the name "seaside finch" was given by Wilson to *Ammodramus maritimus* from habitat. *Junco hyemalis* was called "snowbird" by the early settlers, from the fact of its appearance in the late autumn and at the onset of winter in the coastal plain region. "Junco" is a comparatively late adoption in order to avoid confusion with the snow bunting, *Plectrophenax nivalis*.

The "house wren" is so called by Bartram, and the "marsh wren" likewise (the latter most likely referring to the long-billed species). Wilson, correcting earlier errors, gave the title "winter wren" to *T. hiemalis*.

"Chimney swallow" is an old name for the "chimney swift" and is given as such by Kalm, Bartram, and early writers.

"*T. melodes*, the wood thrush," is so called by Bartram. Wilson named the "hermit thrush" from its habitat and its retiring habits.

The Cowbird was "the cow-pen bird" of Catesby, and likewise of Audubon, and the "cow bunting" of Wilson. "Meadow lark" first appears in Wilson. Bartram calls it "the great meadow lark," and Catesby "the large lark." Pennant, nearer the truth, calls it the "crescent stare." Wilson also speaks of "old field lark" as its common name in Virginia. The "shore lark" is so called by Pennant. Catesby calls it "the lark," Bartram the "skylark," and Wilson the "horned lark."

Several of our American swallows received names indicative of habit or habitat. "Barn swallow" originated as a specific title with Barton. It was the "house swallow" of Bartram. The bank swallow is the "bank martin" of Bartram. "Cliff" and "eave" swallow are names of *Petrochelidon lunifrons* according to the particular nesting site adopted by this species. I have failed to find any early reference to the name "tree swallow" for *T. bicolor*, the "white-bellied swallow" of earlier authors. It appears to have come into use at a comparatively late period.

Bartram speaks of *Ampelis cedrorum* as "crown bird" or "cedar bird," the latter its current name.

V. NAMES SUGGESTED BY COLOR OR OTHER EXTERNAL FEATURE

A large number of our American bird names owe their origin to color or to some conspicuous external feature. The "great crested flycatcher" of Wilson is the "great crested yellow-bellied flycatcher" of Bartram and the "crested flycatcher" of Catesby. The word "great" evidently originated with Bartram. "Baltimore," as applied in the vernacular to *Icterus galbula*, was first used in ornithological literature by Catesby—"The Baltimore bird"—the name being derived from its color pattern, that of the livery of the Calverts (Lord Baltimore). Bartram calls it "Baltimore bird or hang nest." The specific appellation "orchard" appears first to have been bestowed by Wilson upon *Icterus spurius*, which was the "bastard Baltimore" of Catesby. Wilson goes to some length to set things right concerning this species. "Scarlet," as applied to the tanager, appears first in Edwards as the "scarlet sparrow." Pennant calls this species "Canada tanager." The "summer redbird" is so called and figured by Catesby. Bartram speaks of it as the "sandhill redbird of Carolina." Among the sparrows and grosbeaks there are a number of species, the names of which have a color origin. "Red poll," given to a species of *Acanthis*, appears as the "lesser red-headed linnet" and "lesser redpole," of Ray and Pennant. "Linnet" is an ancient name common in several European languages and is in reference to the fondness of these birds for the seeds of the flax. Bartram undoubtedly refers to this species under the name of "hemp bird." "Purple," as applied to *Carpodacus purpureus*, first appears in Catesby's work as "purple finch" and is a monumental witness of an inability to properly discriminate either between two very different shades of color or in the use of the right word. "White-throated sparrow" is so called by Edwards from a drawing of the species sent him by Bartram, who speaks of it in his Travels as "The large brown white-throat sparrow." *Zonotrichia leucophrys* is the "white-crowned bunting" of Pennant. The vernacular of *Passerella iliaca* has been contracted from the

earlier "fox-colored" (or "colored") to simple "fox sparrow." Bartram calls it "the red or fox-colored ground or hedge sparrow." Barton, in his Fragments, speaks of this species' name in New York as "the shepherd." Our modern "cardinal" is undoubtedly of French origin. Catesby gives it its English title of "red bird" and also "Le Cardinal." It is "the red bird or Virginia nightingale" of Bartram and other early writers. Catesby figures *Guiraca cærulea* as "the blew grosbeak." "Rose-breasted" (Wilson) may be traced to *Le Rose Gorge* of Buffon and "red-breasted grosbeak" of Pennant. *Passerina cyanea* is "the blew linnet" of Catesby, who further alludes to it as the "indigo bird of Americans." The "painted finch" is so called by Catesby, and Bartram likewise adds its other title of "nonpareil." "Lazuli" was bestowed upon *P. amœna* by Say.

Pennant first uses the name "black-throated bunting" for *Spiza americana*, but Bartram mentions this species under the title "*Calandra pratensis*, the May bird." "Dickcissel," its modern name, appears to have originated through Mr. Robert Ridgway from Middle West localities. Wilson borrowed the term "sharp-tailed" for *Ammodramus caudacutus* from Turton. "Lark," as applied to two species of Fringillidæ—*Chondestes grammacus* and *Calamospiza melanocorys*—was bestowed upon these different birds, in the one case by Say and in the other by Townsend, in view of their lark-like appearance and habits.

Among the warblers we have a host of color names. "Mourning warbler" we owe to its discoverer, Wilson. The summer warbler or "yellow warbler" was "the yellow titmouse" of Catesby, "the summer yellow bird" of Bartram, the "yellow poll" of Latham and Pennant, and the "blue-eyed yellow warbler" of Wilson. Say first described the orange-crowned warbler. *Mniotilta varia* was the "black and white creeper" of Edwards. In his Travels Bartram calls it the "blue and white striped or pied creeper." Of the prothonotary warbler Pennant says: "Inhabits *Louisiana*. Called there *le Protonotaria;* but the reason has not reached us." Probably in allusion to the vestures of that office. Many species of warblers were earlier known by the various names of "flycatcher," "tit-

mouse," and "creeper," according to their peculiar habits, the specific vernacular being mainly in relation to color. *Dendroica cœrulescens* was the "blue flycatcher" of Edwards, the "black-throat" of Pennant; the "black-throated warbler" of Latham, and the "black-throated blue warbler" as first applied by Wilson. Wilson first named the "cærulean warbler." The "black poll warbler" appears as such in Latham and Pennant, "poll" or "pole" being an early name for "head" as in our "poll tax." The "yellow-throated warbler" was "the yellow-throated creeper" of Catesby. The "blue-winged yellow warbler" was formerly confused with the "pine creeper" of Catesby, hence *pinus* as applied to this species of *Helminthophila.* Its vernacular is a clear translation by Wilson of Bartram's "*Parus aureus alis ceruleis*, blue-winged yellow bird." In like manner *H. chrysoptera* was the "*Parus alis aureus*" of Bartram, the "golden-winged flycatcher" of Edwards (from Bartram), and the "golden-winged warbler" of Wilson and later authors. Wilson first bestowed the names "bay-breasted" and "chestnut-sided" upon *D. castanea* and *D. pensylvanica.* The former was Bartram's "little chocolate breast titmouse" and the latter his "golden crown flycatcher." This last species, also, was the "red-throated flycatcher" of Edwards and the "bloddy-side warbler" of Turton as a result of Edwards's badly colored plate. *D. virens* was the "green black-throated flycatcher" of Bartram and the "black-throated green flycatcher" of Edwards. The "hooded warbler" is figured by Catesby under the name of "the hooded titmouse."

"Black-cap titmouse" is Bartram's name for the species, and probably also its near relative *P. carolinensis.* The "olive-backed thrush" was first so-called by Giraud. *T. fuscescens* was called "tawny thrush" by Wilson. "Bluebird" is an early name. The species is figured by Catesby as "the blew-bird." Pennant calls it the "blue-backed red-breast." *Lanius ludovicianus* was called the "logger head shrike" or "loggerhead" by Wilson, as its common name in the South.

Most of our species of woodpeckers early received their names from color markings or other external feature, as "red-headed,"

"yellow-bellied," "golden-winged," "pileated," "downy," "hairy," "ivory-billed," etc. The word "flicker," as a vernacular of *Colaptes auratus*, probably originated from the bird's call notes. It is referred to by Wilson.

VI. NAMES SUGGESTED BY LOCALITY (PLACE-NAMES) OR IN HONOR OF SOME PERSON

A curious misapprehension as to the significance of the current English name of *Ammodramus sandwichensis savanna* seems to exist in ornithological literature as revealed by its orthography. Wilson distinctly refers to the city of Savannah as the locality where he states he first discovered the species, and he so spells its name in the English title. Its specific name, however, he gives as "savanna." In our current literature this last appears as the method of spelling the bird's name in English, which is clearly misleading. In its general application "savanna" might be very appropriate in view of the species' habitat, but Wilson intended it otherwise, and "Savannah sparrow" is the proper form of the English name.

The term "evening" in the vernacular of *Hesperiphona vespertina* as given to the species by Cooper conveys, as does the scientific name, the idea of the west or the place of sunset.

Geothlypis trichas was called by Bartram "the olive colored yellow throated wren." Of the bird's present English name I find the following interesting reference in Edwards's Gleanings: "J. Petizer, in his Gazophylacium, plate vi, has given the figure of a bird, which I believe to be the same with this; for which reason I continue the name he has given it . . . '*Avis Marylandica gutture luteo*, the Maryland yellowthroat. This the Rev. Mr. H. Jones sent me from Maryland.'" Edwards later received the bird from Bartram with a drawing "very neatly and exactly done, by Mr. William Bartram, of Pennsylvania, who hath enabled me to give a further account of this bird, for he says it frequents thickets and low bushes by runs (of water, I suppose, he means) and low grounds; it leaves Pennsylvania at the approach of winter, and is supposed to go to a warmer climate."

To Wilson we owe the place names of five of our species of warblers—the Kentucky, Connecticut, Tennessee, Nashville, and Cape May—from the State or locality of the first capture by him of the species in question. John Cassin named a species of Vireo "Philadelphia" after the city in the neighborhood of which he obtained his type specimen.

Thryothorus ludovicianus obtained its vernacular through Bartram—"(regulus magnus) the great wren of Carolina." This Wilson transposed into "Great Carolina wren."

The "Blackburnian warbler" is so called by Pennant and Latham, and was named in honor of Mrs. Hugh Blackburn, of London.

A number of our birds acquired their names in the first half of the last century in honor of certain persons known to their describers, as Lincoln's, Henslow's, LeConte's, and Harris's sparrows; Townsend's, Audubon's, Swainson's, and Bachman's warblers; Lewis's woodpecker; Clark's nutcracker; Steller's and Woodhouse's jays, and many others of early and recent date.

"Louisiana," as applied to the species of tanager (*Piranga ludoviciana*), and the water thrush (*Seiurus motacilla*) refers to the region embraced in the Louisiana Purchase, not to the present State of that name. "Florida," "Canada," "California," "Hudsonian," and other regional names have in like manner been applied to certain species, as "Florida jay," "Canada jay," "Canadian warbler," "California woodpecker," "Hudsonian chickadee," and so forth.

The matter as presented in the foregoing sketch does not pretend to list all of the species and varieties of North American land birds. It is only a sketch or outline of a most attractive subject and was written partly for the purpose of gathering together what knowledge we have of the history and origin of our more familiar bird names.

QUESTIONS AND EXERCISES

This selection is an illustration again of the process of division. It shows the skillful handling of a mass of complex facts upon some-

what larger scale than the preceding. The questions given in connection with *The Migrations of Races of Men* may easily be adapted to the present selection.

Exercise 1. Write a composition upon one of the following subjects. Group the material carefully under a few large heads.

Our foods and where they come from.
Sources of the names of persons.
How plants obtain food.
Inventions of the future.

Exercise 2. Write a composition upon the subject, The Sources of English Words, making a careful division of your material and giving examples plentifully.

Exercise 3. Group in a way similar to the selection given above the names of the following classes of objects:

Military weapons.
Vehicles for land locomotion.
Fishes.
Popular names of vegetables.

(The appendix of the International Dictionary may be useful in helping to make a list of the terms to be classified.)

MODERN CHEMISTRY AND MEDICINE [1]

THEODORE WILLIAM RICHARDS

In these days science no longer needs justification as a subject worthy of man's earnest devotion. The gain in exact knowledge of the forces and materials of the universe is recognized on all sides as bringing with it promise of incalculable benefit to humanity. The full importance of this new light, in its bearing upon the amelioration of the human lot, is only just beginning to be realized.

In keeping with the increasing appreciation of the value of scientific research to humanity, there exists to-day among

[1] An address delivered at the seventy-fifth anniversary of the founding of Haverford College. Reprinted from *Atlantic Monthly*, vol. 103, by permission of the author and the publishers.

scientific men the effort to relate each particular science to every other, and to associate all together in a coherent whole, without losing sight of the need of accuracy in each part. The existence of such composite branches of study as physical chemistry, biochemistry, physiological botany, and so forth, are one indication of the broader outlook; and some of the greatest modern scientific advances are being made along the border lines between the different sciences. Nature is, after all, a unit, and our classifications of her closely related phenomena into special topics are partly arbitrary.

This effort to relate the various sciences to one another is not only helpful to science as a whole, it is likewise beneficial to the individual worker. A man's mental outlook must be broadened by an attempt to trace the relation of his special task to the manifold other activities and needs of humanity.

The particular branch of science called chemistry has many relations to human life, as well as to other sciences. It forms an essential part of any philosophy of nature; it serves as an admirable means of intellectual discipline; it guides the manufacturer and the merchant toward efficiency in production and purity of product; but, perhaps most important of all, it holds the key which alone can unlock the gate to really fundamental knowledge of the hidden causes of health and disease. This is one of the most precious and vital ways in which any branch of science can serve humanity in the years to come.

Ten centuries ago, in the time of the alchemists, chemistry was called "the handmaid of medicine;" to-day this relationship is not weaker, but rather much stronger. The object of the present article is to call attention very briefly to some of the ways in which modern chemistry may be able to help the theory and practice of medicine.

That a close relationship between chemistry and medicine exists is clear to every one. Our bodies are wholly built up of chemical substances, and all the manifold functions of the living organism depend, at least in part, upon chemical reactions. Chemical processes enable us to digest our food, keep us warm, supply us with muscular energy. It is highly probable

that even the impressions of our senses, and the thoughts of our brains, as well as the mode of conveying these through the nerves, are all concerned more or less intimately with chemical reactions. In short, the human body is a wonderfully intricate chemical machine; and its health and illness, its life and death, are essentially connected with the coördination of a variety of complex chemical changes.

This intricacy of the living body demands clear sight and profound knowledge for its full understanding; and the chemistry of former days was much too simple and superficial to be a very useful guide in the puzzling labyrinth of many converging and crossing paths. Now, circumstances have wholly changed. Chemistry is fast approaching physics in accuracy, and is expanding beyond physics in scope. As chemical understanding has increased, the gap between the simpler phenomena of the chemical laboratory and the more complicated changes underlying organic life has become smaller and smaller. The intelligent physician is perceiving this, and welcomes the help which the rapidly advancing science of chemistry can give him. An eminent pathologist recently said that in the study of the cell and its growth, normal as well as abnormal, the investigating medical scientist has come to the place where he must fall back upon chemical knowledge, because he perceives that the action of the cell depends upon the nature and quantity of the various chemical substances of which it is made. As the cell is the basis of all life, and as our bodies consist simply of aggregations of a great body of cells, each of which is governed by chemical laws, it is clear that chemistry must underlie all the vital functions.

Chemistry may be of use to medicine in at least three quite different ways. One of these is concerned with discovering the components of things. This kind of chemistry is called analytical chemistry. Another way in which chemistry can help medicine depends upon the ability of the modern chemist, not only to find out what the things are made of, but also to discover how the parts are put together. This branch of chemistry is called structural chemistry, because it has to do not only

with the materials, but also with the way in which these materials are arranged. Yet another method of helpfulness comes from a still more recent development of chemistry, commonly called physical chemistry, which deals with the phenomena lying on the border line between physics and chemistry—especially that part of the border line concerning the relation of energy to material. The physical chemist must know, not only what things are made of and how these elements are put together, but also what energy is concerned in putting them together, and what energy is set free when they are decomposed.

Each of these three kinds of chemistry can greatly aid the science and art of medicine—and no philosopher is needed to proclaim how much more effective their assistance may be than the old method of observing merely the outward appearance of fluid and tissue.

Let us now briefly glance in detail at the various aspects of these three modes of helpfulness, taking them in the order in which they have just been mentioned. First comes the field of the analytical chemist. As has been said, the human body is a chemical machine. It is composed entirely of chemicals, and is actuated exclusively by chemical energy. The analytical chemist is able to tell us the composition of each one of the manifold substances that compose this intricate machine. He is able not only to discover the various elements which are present, but also to estimate with considerable precision their exact amounts. He can analyze food, as well as the various parts and secretions of the body, and can determine the relation between the composition of the food which is eaten and the resulting bodily substance. This is all obviously of great value, for it shows us at once in a general way what elements ought to enter into the food; and moreover, in cases of disease it gives us excellent clues to the manner in which the various functions of the body depart from the normal, and thus confers important aid in diagnosis and the suggestion of suitable treatment. But this is an old and obvious story, hence I will not dwell further upon the analytical side of the application of chemistry to medicine, important as it is.

Let us now turn to the second aspect of the subject: namely, the relation of structural chemistry to medicine. So recent is the development of the subject that the very idea of structural chemistry is not yet a part of the average liberally educated man's equipment.

Structural chemistry had its origin in the discovery that two substances might be made up of exactly the same percentage amount of exactly the same elements, and yet be entirely different from each other. This fact, that two things may be exactly alike as to their constituents, but very different in their properties, implies that there must be difference of arrangement of some kind or other. We can obtain the clearest conception of this idea with the help of the atomic hypothesis. If the smallest particles of any given compound substance are built up of still smaller atoms of the various elements concerned, it is clear that we can conceive of different arrangements of these atoms, and it is reasonable to suppose that the particular arrangements might make considerable difference in the nature of the resulting compounds. Everywhere in life arrangement is significant. In the case of numbers the combination 191 is very different from 911, although each contains the same individual signs. Why may not arrangement be significant in the case of atoms?

It is not possible in this brief review to explain exactly how chemists obtain a notion of the arrangement of atoms which build up the particles (or molecules) of each substance. We depend upon two methods of working: one, the splitting-up of the compound and finding into what groups it decomposes; the other, the attempt to build up from these or similar groups the original compound. Just as among the fragments of a collapsed building you will find bits enough to show whether it was a dwelling, a stable, or a machine-shop, so among the fragments of a broken-down substance you will find bits of its structure still remaining together, enough to indicate something of the original grouping. Each different chemical structure will leave a different kind of chemical débris. If from similar fragments the original substance can be constructed

by suitable means, the evidence is strong that some knowledge of the structure has been gained.

As regards the usefulness of structural chemistry to medicine, we cannot but see at once its vast importance. If the binding together of infinitesimal atoms in different ways modifies the properties of the resulting substances differently, it is obvious that the particular mode of binding together every one of the complicated compounds constituting our bodies is of vital importance to us. Moreover, in the case of our food, the arrangement alone of the atoms may make all the difference between nourishment and poison.

It is easy to see why these different structures should have different effect in the body. Living, in the case of animals, is a continual process of breaking down more complicated structures into simpler ones; and it is clear that this breaking down will happen in different ways with different groupings, and thus produce different results.

The knowledge of the atomic arrangement of the various substances composing the body is not only bound to furnish an invaluable guide in the study of physiology, pathology, and hygiene, but has already led to the logical discovery of entirely new medicines, built up artificially in the laboratory to fit the especial needs of particular ailments, and to the rational use of foods. In the years to come, these gains are bound to multiply.

Thus in the future the physician may do his work, not with a serum or virus of doubtful composition and value, but rather with pure substances built up in the chemical laboratory,—substances with their groups of atoms so arranged by subtle science as to accomplish the reconstruction of worn-out organs or the destruction of malignant germs without working harm of any kind. We may thus dream of the attainment of an artificial immunity from smallpox, for example, as much superior to vaccination as this is superior to the old inoculation.

Beneficent substances of this kind will not often be discovered by accident; the number of possible arrangements is far too great. In order to know all there is to be known about

the matter, the structure of each intricate substance existing in the body must be found, and the arrangement of the atoms in each particle of our complex organism. Until this shall be done, we cannot be in a position to predict with any reasonable certainty what is going to happen to these substances in the round of their daily functions, or how they are likely to be influenced by disease. This is a problem so vitally important that it would be hard to exaggerate its significance to posterity.

As I have said, modern knowledge now demands of the chemist that he should know, not only the elements composing all things and how these elements are put together, but also how great an output of energy is involved in every change to which they may be subjected.

Now, there is no doubt that energy is the immediate cause of every action in the known universe. Without any kind of energy, the whole universe would be quiescent, dark, piercingly cold, asleep. A world imbued with physical energies, but without chemical energy, might revolve and have light and warmth; but it could possess no organic life, for life is based upon the action of chemical energy. Thus the study of chemical energy is another very important human problem.

Physical chemistry has to do with the relation of each of the various kinds of energy to chemical change. It deals with the acting, driving forces which make life possible, and in each of its many aspects it brings new intelligence to bear upon the working of the living mechanism.

Physical chemistry treats among other topics the chemical relations of the changes from solid to liquid, and from liquid to gas, and discusses the nature of solutions and mixtures of all kinds. As the living body is composed of solids and liquids, and depends upon the gases of the atmosphere for promotion of the chemical changes animating it, and as solutions and mixtures are present in every cell, the laws and theories of physical chemistry are intertwined with every fact of physiology.

Again, physical chemistry deals with the relation of heat to chemical change. The output of energy in the form of heat in every chemical reaction is worthy of study, but especially

ought man to investigate the steps by which is evolved all animal heat—and this is exclusively due to chemical reaction. Moreover, physical chemistry studies the effect of changing temperature upon the speed and tendency of chemical action, —a matter of importance in the study of fevers and other abnormal conditions, as well as in the tracing of the marvelous hidden mechanism by which the body is kept at almost constant temperature.

This dynamic chemistry of the future does not stop here, however. Within its province lie also the recently found relations of chemistry and electricity, bearing perhaps upon some of the mysteries of nervous action, and furnishing much intelligence concerning the nature of solutions in general. More important, perhaps, than all this is the branch of the subject called photochemistry, the chemistry of light, which promises to give great assistance in the interpretation of the changes occurring in the leaves of plants under the influence of sunlight. Through the agency of light alone, nature is able to build up the intricate compounds needed to provide all animals with food; and, until we understand the growth of the vegetable, we cannot hope to understand that of the animal.

A moment's thought will show that this chemistry of substances in action—that is, the chemistry of energy—brings with it a promise of helpfulness to future generations, which perhaps exceeds that of any other science. For the study of the inert substance from which life has departed, no matter how accurate this study may be, cannot give us a true knowledge of its real office, any more than we can predict from the appearance of a stuffed bird in a museum its complete habit of life. In order to understand the process of living, one must see the substances in action and study their behavior under the influence of the manifold forces which play around them; and this is the aim of physical chemistry.

I have outlined very briefly a few of the ways in which science holds out great promise of help to suffering humanity in the future. To some the point of view may have seemed materialistic; we must remember, however, that science does not

attempt to fathom the ultimate mystery, but deals with the facts of nature only. The greatest mysteries of life seem almost as far from solution as ever. Just what relations exist, for example, between chemical change and thought, what permanent alterations of chemical structure cause memory, we know not. Life we have never been able to produce from dead material alone. Personality and heredity defy the chemist, as they do the physiologist and the psychologist. But let us not be impatient. Though it is impossible to predict how far we shall be enabled by means of our limited minds to penetrate into the mysteries of a universe immeasurably vast and wonderful, we may nevertheless comfort ourselves with the thought that each step gained brings new blessing to humanity and new inspiration to greater endeavor.

QUESTIONS AND EXERCISES

This selection illustrates division in another aspect. In *History of the Popular Names of American Birds* the process was almost identical with classification, differing from it only in completeness. But in the present selection, the object is simply to make a separation of the subject into its natural parts, and thereby so to simplify a subject too large or complex to be taken in at a single glance that it may be apprehended with brevity and economy. In some degree, this process is present in all writing of any length. Even when the writer is selecting the paragraph headings for his article, he is making use of the process of division. It is essentially a process of thought, of reason, demanding intelligence and patience, and making for organic unity. It may sound paradoxical to say that organic unity is gained through division, yet such is the case. In systematic thinking there is always careful grouping of ideas, and the whole becomes clearer from this grouping or dividing. A good division is a mark of mental grasp; the better it is done, the more grasp there is likely to be of the material. Furthermore, since the mind grasps a subject more surely if but one phrase is presented at a time, the dividing of a subject helps the reader. As the division is for the sake of the reader, it will be good in proportion as it helps him to follow. Simple, natural divisions are the most helpful, and any good division must be obtained by dividing on a single principle. Unless there is some definite basis for the division, the grouping will be haphazard with

confusion as the result for the reader. Although this process has been implicit in much of the work already done, still it will be helpful to put it more definitely in mind by study of the present selection.

1. What is the central idea of this address? Where does the writer state the general heads under which he will discuss this central idea? Is it an advantage to have the division explicitly laid before the reader? To how much completeness does the writer pretend in this division? Would further analysis have been helpful?

2. Is each of these divisions clearly expounded by particulars and details or illustrative material?

3. How far is the great clearness of arrangement seemingly due to the paragraph structure?

4. Is the address convincing? What parts impress you most strongly, and why?

Exercise 1. Write a composition of 500 words or so on one of the following subjects, making some simple division into three or four parts:

The relation of waterfalls to industry.
The relation of chemistry to engineering.
How climate influences occupations and character.
Adaptation of plants to climate.
Photography as an aid to astronomy.
The relation of fraternities to the college.
Our rights over animals and our duties toward them.
The relation between geology and mineralogy.
The proper relation between rich and poor.
The proper relations between employer and employed.
Relations of business to politics.
The place of the public library in the community.
The relation of the faculty to the student body.
Influence of geography on history.
Conflict between science and religion.
Effects of aviation on war and commerce.
Applications of electricity to farming.
The American college and life.
Value of bees in fruit culture.
Influence of forests on water storage.
The relation of mathematics to engineering.
The value of the study of English to the engineer or scientist.
Why a student who purposes to study medicine should study physics.

Value of scientific education to the farmer.
The influence of profit-sharing on the sharers.
Relation of railways to business.

Exercise 2. "Not only are the sciences involved with each other," says Herbert Spencer, "but they are all inextricably interwoven with the complex web of the arts, and are only conventionally independent of it. Originally the two were one, and there has been a perpetual inosculation of the two ever since. Science has been supplying art with higher generalizations and more completely qualitative previsions; art has been supplying science with better materials and more perfect instruments. . . . And all along, this interdependence has been growing closer, not only between the arts and sciences, but among the arts themselves and among the sciences themselves." Make this statement clear by means of illustrations, etc.

STATEMENT OF A PROBLEM

PROGRESS AND POVERTY: THE PROBLEM[1]

HENRY GEORGE

THE present century has been marked by a prodigious increase in wealth-producing power. The utilization of steam and electricity, the introduction of improved processes and labor-saving machinery, the greater subdivision and grander scale of production, the wonderful facilitation of exchanges, have multiplied enormously the effectiveness of labor.

At the beginning of this marvelous era it was natural to expect, and it was expected, that labor-saving inventions would lighten the toil and improve the condition of the laborer; that the enormous increase in the power of producing wealth would make real poverty a thing of the past. Could a man of the last century—a Franklin or a Priestley—have seen, in a vision of the future, the steamship taking the place of the sailing vessel, the railroad train of the wagon, the reaping machine of the scythe, the threshing machine of the flail; could he have heard the throb of the engines that in obedience to human will, and for the satisfaction of human desire, exert a power greater than that of all the men and all the beasts of burden of the earth combined; could he have seen the forest tree transformed into finished lumber—into doors, sashes, blinds, boxes or barrels, with hardly the touch of a human hand; the great workshops where boots and shoes are turned out by the case with less labor than the old-fashioned cobbler could have put on a sole; the factories where, under the eye of a girl, cotton becomes

[1] Reprinted from *Progress and Poverty*, by permission of the publishers, Messrs. D. Appleton & Co.

cloth faster than hundreds of stalwart weavers have turned it out with their hand-looms; could he have seen steam hammers shaping mammoth shafts and mighty anchors, and delicate machinery making tiny watches; the diamond drill cutting through the heart of the rock, and coal oil sparing the whale; could he have realized the enormous saving of labor resulting from improved facilities of exchange and communication—sheep killed in Australia eaten fresh in England, and the order given by the London banker in the afternoon executed in San Francisco in the morning of the same day; could he have conceived of the hundred thousand improvements which these only suggest, what would he have inferred as to the social condition of mankind?

It would not have seemed like an inference; further than the vision went, it would have seemed as though he saw; and his heart would have leaped and his nerves would have thrilled, as one who from a height beholds just ahead of the thirst-stricken caravan the living gleam of rustling woods and the glint of laughing waters. Plainly, in the sight of the imagination, he would have beheld these new forces elevating society from its very foundations, lifting the very poorest from the possibility of want, exempting the very lowest from anxiety for the material needs of life; he would have seen these slaves of the lamp of knowledge taking on themselves the traditional curse, these muscles of iron and sinews of steel making the poorest laborer's life a holiday, in which every high quality and noble impulse could have scope to grow.

And out of these bounteous material conditions he would have seen arising, as necessary consequences, moral conditions realizing the golden age of which mankind have always dreamed. Youth no longer stunted and starved; age no longer harried by avarice; the child at play with the tiger; the man with the muck-rake drinking in the glory of the stars! Foul things fled, fierce things tamed; discord turned to harmony! For how could there be greed where all had enough? How could the vice, the crime, the ignorance, the brutality, that spring from poverty and the fear of poverty, exist where poverty had vanished?

Who should crouch where all were freemen? who oppress where all were peers?

More or less vague or clear, these have been the hopes, these the dreams born of the improvements which give this wonderful century its preëminence. They have sunk so deeply into the popular mind as to radically change the currents of thought, to recast creeds and displace the most fundamental conceptions. The haunting visions of higher possibilities have not merely gathered splendor and vividness, but their direction has changed—instead of seeing behind the faint tinges of an expiring sunset, all the glory of the daybreak has decked the skies before.

It is true that disappointment has followed disappointment, and that discovery upon discovery, and invention after invention, have neither lessened the toil of those who most need respite, nor brought plenty to the poor. But there have been so many things to which it seemed this failure could be laid, that up to our time the new faith has hardly weakened. We have better appreciated the difficulties to be overcome; but not the less trusted that the tendency of the times was to overcome them.

Now, however, we are coming into collision with facts which there can be no mistaking. From all parts of the civilized world come complaints of industrial depression; of labor condemned to involuntary idleness; of capital massed and wasting; of pecuniary distress among business men; of want and suffering and anxiety among the working classes. All the dull, deadening pain, all the keen, maddening anguish, that to great masses of men are involved in the words "hard times," afflict the world to-day. This state of things, common to communities differing so widely in situation, in political institutions, in fiscal and financial systems, in density of population and in social organization, can hardly be accounted for by local causes. There is distress where large standing armies are maintained, but there is also distress where the standing armies are nominal; there is distress where protective tariffs stupidly and wastefully hamper trade, but there is also distress

where trade is nearly free; there is distress where autocratic government yet prevails, but there is also distress where political power is wholly in the hands of the people; in countries where paper is money, and in countries where gold and silver are the only currency. Evidently, beneath all such things as these, we must infer a common cause.

That there is a common cause, and that it is either what we call material progress or something closely connected with material progress, becomes more than an inference when it is noted that the phenomena we class together and speak of as industrial depression, are but intensifications of phenomena which always accompany material progress, and which show themselves more clearly and strongly as material progress goes on. Where the conditions to which material progress everywhere tends are most fully realized—that is to say, where population is densest, wealth greatest, and the machinery of production and exchange most highly developed—we find the deepest poverty, the sharpest struggle for existence, and the most enforced idleness.

It is to the newer countries—that is, to the countries where material progress is yet in its earlier stages—that laborers emigrate in search of higher wages, and capital flows in search of higher interest. It is in the older countries—that is to say, the countries where material progress has reached later stages—that widespread destitution is found in the midst of the greatest abundance. Go into one of the new communities where Anglo-Saxon vigor is just beginning the race of progress; where the machinery of production and exchange is yet rude and inefficient; where the increment of wealth is not yet great enough to enable any class to live in ease and luxury; where the best house is but a cabin of logs or a cloth and paper shanty, and the richest man is forced to daily work—and though you will find an absence of wealth and all its concomitants, you will find no beggars. There is no luxury, but there is no destitution. No one makes an easy living, nor a very good living; but every one *can* make a living, and no one able and willing to work is oppressed by the fear of want.

But just as such a community realizes the conditions which all civilized communities are striving for, and advances in the scale of material progress—just as closer settlement and a more intimate connection with the rest of the world, and greater utilization of labor-saving machinery, make possible greater economies in production and exchange, and wealth in consequence increases, not merely in the aggregate, but in proportion to population—so does poverty take a darker aspect. Some get an infinitely better and easier living, but others find it hard to get a living at all. The "tramp" comes with the locomotive, and almshouses and prisons are as surely the marks of "material progress" as are costly dwellings, rich warehouses, and magnificent churches. Upon streets lighted with gas and patrolled by uniformed policemen, beggars wait for the passer-by, and in the shadow of college, and library, and museum, are gathering the more hideous Huns and fiercer Vandals of whom Macaulay prophesied.

This fact—the great fact that poverty and all its concomitants show themselves in communities just as they develop into the conditions towards which material progress tends—proves that the social difficulties existing wherever a certain stage of progress has been reached, do not arise from local circumstances, but are, in some way or another, engendered by progress itself.

And, unpleasant as it may be to admit it, it is at last becoming evident that the enormous increase in productive power which has marked the present century and is still going on with accelerating ratio, has no tendency to extirpate poverty or to lighten the burdens of those compelled to toil. It simply widens the gulf between Dives and Lazarus, and makes the struggle for existence more intense. The march of invention has clothed mankind with powers of which a century ago the boldest imagination could not have dreamed. But in factories where labor-saving machinery has reached its most wonderful development, little children are at work; wherever the new forces are anything like fully utilized, large classes are maintained by charity or live on the verge of recourse to it; amidst

the greatest accumulations of wealth, men die of starvation, and puny infants suckle dry breasts; while everywhere the greed of gain, the worship of wealth, shows the force of the fear of want. The promised land flies before us like the mirage. The fruits of the tree of knowledge turn as we grasp them to apples of Sodom that crumble at the touch.

It is true that wealth has been greatly increased, and that the average of comfort, leisure, and refinement has been raised; but these gains are not general. In them the lowest class do not share.[1] I do not mean that the condition of the lowest class has nowhere nor in anything been improved; but that that is nowhere any improvement which can be credited to increased productive power. I mean that the tendency of what we call material progress is in nowise to improve the condition of the lowest class in the essentials of healthy, happy human life. Nay, more, that is still further to depress the condition of the lowest class. The new forces, elevating in their nature though they be, do not act upon the social fabric from underneath, as was for a long time hoped and believed, but strike it at a point intermediate between top and bottom. It is as though an immense wedge were being forced, not underneath society, but through society. Those who are above the point of separation are elevated, but those who are below are crushed down.

This depressing effect is not generally realized, for it is not apparent where there has long existed a class just able to live. Where the lowest class barely lives, as has been the case for a long time in many parts of Europe, it is impossible for it to get any lower, for the next lowest step is out of existence, and no tendency to further depression can readily show itself. But in the progress of new settlements to the conditions of older communities it may clearly be seen that material progress does not merely fail to relieve poverty—it actually produces it. In the

[1] It is true that the poorest may now in certain ways enjoy what the richest a century ago could not have commanded, but this does not show improvement of condition so long as the ability to obtain the necessaries of life is not increased. The beggar in a great city may enjoy many things from which the backwoods farmer is debarred, but that does not prove the condition of the city beggar better than that of the independent farmer.

United States it is clear that squalor and misery, and the vices and crimes that spring from them, everywhere increase as the village grows to the city, and the march of development brings the advantages of the improved methods of production and exchange. It is in the older and richer sections of the Union that pauperism and distress among the working classes are becoming most painfully apparent. If there is less deep poverty in San Francisco than in New York, is it not because San Francisco is yet behind New York in all that both cities are striving for? When San Francisco reaches the point where New York now is, who can doubt that there will also be ragged and barefooted children on her streets?

This association of progress and poverty is the great enigma of our times. It is the central fact from which spring industrial, social, and political difficulties that perplex the world, and with which statesmanship and philanthropy and education grapple in vain. From it come the clouds that overhang the future of the most progressive and self-reliant nations. It is the riddle which the Sphinx of Fate puts to our civilization, and which not to answer is to be destroyed. So long as all the increased wealth which modern progress brings goes but to build up great fortunes, to increase luxury and make sharper the contrast between the House of Have and the House of Want, progress is not real and cannot be permanent. The reaction must come. The tower leans from its foundations, and every new story but hastens the final catastrophe. To educate men who must be condemned to poverty, is but to make them restive; to base on a state of most glaring social inequality political institutions under which men are theoretically equal, is to stand a pyramid on its apex.

All-important as this question is, pressing itself from every quarter painfully upon attention, it has not yet received a solution which accounts for all the facts and points to any clear and simple remedy. This is shown by the widely varying attempts to account for the prevailing depression. They exhibit not merely a divergence between vulgar notions and scientific theories, but also show that the concurrence which should exist between those who avow the same general theories breaks up

upon practical questions into an anarchy of opinion. Upon high economic authority we have been told that the prevailing depression is due to over-consumption; upon equally high authority, that it is due to over-production; while the wastes of war, the extension of railroads, the attempts of workmen to keep up wages, the demonitization of silver, the issue of paper money, the increase of labor-saving machinery, the opening of shorter avenues to trade, etc., etc., are separately pointed out as the cause, by writers of reputation.

And while professors thus disagree, the ideas that there is a necessary conflict between capital and labor, that machinery is an evil, that competition must be restrained and interest abolished, that wealth may be created by the issue of money, that it is the duty of government to furnish capital or to furnish work, are rapidly making way among the great body of people, who keenly feel a hurt and are sharply conscious of a wrong. Such ideas, which bring great masses of men, the repositories of ultimate political power, under the leadership of charlatans and demagogues, are fraught with danger; but they cannot be successfully combatted until political economy shall give some answer to the great question which shall be consistent with all her teachings, and which shall commend itself to the perceptions of the great masses of men.

It must be within the province of political economy to give such an answer. For political economy is not a set of dogmas. It is the explanation of a certain set of facts. It is the science which, in consequence of certain phenomena, seeks to trace mutual relations and to identify cause and effect, just as the physical sciences seek to do in other sets of phenomena. It lays its foundations on firm ground. The premises from which it makes its deductions are truths which have the highest sanction; axioms which we all recognize; upon which we safely base the reasoning and actions of every-day life, and which may be reduced to the metaphysical expression of the physical law that motion seeks the line of least resistance—viz., that men seek to gratify their wishes with the least exertion. Proceeding from a basis thus assured, its processes, which consist simply

in identification and separation, have the same certainty. In this sense it is an exact science as geometry, which, from similar truths relative to space, obtains its conclusions by similar means, and its conclusions when valid should be as self-apparent. And although in the domain of political economy we cannot test our theories by artificially produced combinations or conditions, as may be done in some of the other sciences, yet we can apply tests no less conclusive, by comparing societies in which different conditions exist, or by, in imagination, separating, combining, adding or eliminating forces or factors of known direction.

I propose in the following pages to attempt to solve by the methods of political economy the great problem I have outlined. I propose to seek the law which associates poverty with progress, and increases want with advancing wealth; and I believe that in the explanation of this paradox we shall find the explanation of those recurring seasons of industrial and commercial paralysis which, viewed independent of their relations to more general phenomena, seem so inexplicable. Properly commenced and carefully pursued, such an investigation must yield a conclusion that will stand every test, and as truth will correlate with all other truth. For in the sequence of phenomena there is no accident. Every effect has a cause, and every fact implies a preceding fact.

That political economy, as at present taught, does not explain the persistence of poverty amid advancing wealth in a manner which accords with the deep-seated perceptions of men; that the unquestionable truths which it does teach are unrelated and disjointed; that it has failed to make the progress in popular thought that truth, even when unpleasant, must make; that, on the contrary, after a century of cultivation, during which it has engrossed the attention of some of the most subtle and powerful intellects, it should be spurned by the statesman, scouted by the masses, and relegated in the opinion of many educated and thinking men to the rank of a pseudo-science in which nothing is fixed or can be fixed—must, it seems to me, be due not to any inability of the science when properly pursued, but to some false step in its premises, or overlooked factor in its

estimates. And as such mistakes are generally concealed by the respect paid to authority, I propose in this inquiry to take nothing for granted, but to bring even accepted theories to the test of first principles, and should they not stand the test, to freshly interrogate facts in the endeavor to discover their law.

I propose to beg no question, to shrink from no conclusion, but to follow truth wherever it may lead. Upon us is the responsibility of seeking the law, for in the very heart of our civilization to-day women faint and little children moan. But what that law may prove to be is not our affair. If the conclusions that we reach run counter to our prejudices, let us not flinch; if they challenge institutions that have long been deemed wise and natural, let us not turn back.

QUESTIONS AND EXERCISES

This first chapter from Henry George's *Progress and Poverty* is a good example of that preliminary analysis of facts and conditions necessary to the working out of a detailed problem. Much often depends upon such analysis: the writer is thereby enabled to take a definite stand toward his material, mark out his course, and marshal his facts intelligently; the reader is at once acquainted with the meaning of the discussion, is enabled to correlate readily every detail offered him and to interpret each in its relation to the discussion as a whole.

1. The chapter serves the purpose of an introduction by stating:
    a. The elements that enter into the problem.
    b. What previous attempts have done to solve the problem.
    c. The nature of a true solution.
    d. The attitude to be taken by the writer in his investigation.

Could this order of topics be improved? Explain the advantages of the present arrangement.

2. For what kind of readers is the discussion intended? Upon what do you base your answer? Does the writer feel that his readers are opposed to his viewpoint or that they are in sympathy with it? Does his feeling on this score in any way determine the selection or the arrangement of his material?

3. In the statement of a scientific problem one usually expects a cold intellectual analysis. Here, however, he notices immediately

evident display of strong feeling on the writer's part. In what ways is it manifested? Should it have been kept hidden?

Exercise 1. Imagine that you are to make a speech at an alumni banquet upon the subject, "Do Athletics at ——— College Need Reform?" Write the opening paragraphs in which you endeavor to set before your hearers a preliminary analysis of facts and conditions. Do not take sides and begin to argue the case. Merely state the problem.

Exercise 2. In 400–600 words state the problem involved in one of the following topics:

Should the college course be shortened?
Elective studies in college.
The negro question.
Overcrowding in large cities.
Teaching English composition.
Conservation of natural resources.
The reduction of iron from its ore.
A substitute for wood pulp in paper manufacture.
The utilization of cobalt, silicon, or tellurium.
The problem of medical inspection of the public schools.
The problem of the prevention of tuberculosis (or typhoid fever).
A bleaching agent that will not injure the fabric upon which it is used.

THE PROBLEMS OF ASTRONOMY[1]

Prof. Simon Newcomb

Assembled, as we are, to dedicate a new institution to the promotion of our knowledge of the heavens, it appeared to me that an appropriate and interesting subject might be the present and future problems of astronomy. Yet it seemed, on further reflection, that, apart from the difficulty of making an adequate statement of these problems on such an occasion as the present, such a wording of the theme would not fully express the idea which I wish to convey. The so-called problems of astronomy

[1] An address at the dedication of the Flower Observatory, University of Pennsylvania, May 12, 1897. Reprinted by permission of the editor from *Science*, May 21, 1897.

are not separate and independent, but are rather the parts of one great problem, that of increasing our knowledge of the universe in its widest extent. Nor is it easy to contemplate the edifice of astronomical science as it now stands, without thinking of the past as well as of the present and future. The fact is that our knowledge of the universe has been in the nature of a slow and gradual evolution, commencing at a very early period in human history, and destined to go forward without stop, as we hope, so long as civilization shall endure. The astronomer of every age has built on the foundations laid by his predecessors, and his work has always formed, and must ever form, the base on which his successors shall build. The astronomer of to-day may look back upon Hipparchus and Ptolemy as the earliest ancestors of whom he has positive knowledge. He can trace his scientific descent from generation to generation, through the periods of Arabian and mediæval science, through Copernicus, Kepler, Newton, La Place, and Herschel, down to the present time. The evolution of astronomical knowledge, generally slow and gradual, offering little to excite the attention of the public, has yet been marked by two cataclysms. One of these is seen in the grand conception of Copernicus that this earth on which we dwell is not a globe fixed in the center of the universe, but is simply one of a number of bodies, turning on their own axes and at the same time moving around the sun as a center. It has always seemed to me that the real significance of the heliocentric system lies in the greatness of this conception rather than in the fact of the discovery itself. There is no figure in astronomical history which may more appropriately claim the admiration of mankind through all time than that of Copernicus. Scarcely any great work was ever so exclusively the work of one man as was the heliocentric system the work of the retiring sage of Frauenburg. No more striking contrast between the views of scientific research entertained in his time and in ours can be seen than that seen in the fact that, instead of claiming credit for his great work, he deemed it rather necessary to apologize for it and, so far as possible, to attribute his ideas to the ancients.

A century and a half after Copernicus followed the second great step, that taken by Newton. This was nothing less than showing that the seemingly complicated and inexplicable motions of the heavenly bodies were only special cases of the same kind of motion, governed by the same forces, that we see around us whenever a stone is thrown by the hand or an apple falls to the ground. The actual motions of the heavens and the laws which govern them being known, man had the key with which he might commence to unlock the mysteries of the universe.

When Huyghens, in 1656, published his Systema Saturnium, where he first set forth the mystery of the rings of Saturn, which, for nearly half a century, had perplexed telescopic observers, he prefaced it with a remark that many, even among the learned, might condemn his course in devoting so much time and attention to matters far outside the earth, when he might better be studying subjects of more concern to humanity. Notwithstanding that the inventor of the pendulum clock was, perhaps, the last astronomer against whom a neglect of things terrestrial could be charged, he thought it necessary to enter into an elaborate defense of his course in studying the heavens. Now, however, the more distant objects are in space—I might almost add the more distant events are in time—the more they excite the attention of the astronomer, if only he can hope to acquire positive knowledge about them. Not, however, because he is more interested in things distant than in things near, but because thus he may more completely embrace in the scope of his work the beginning and the end, the boundaries of all things, and thus, indirectly, more fully comprehend all that they include. From his standpoint

> "All are but parts of one stupendous whole,
> Whose body nature is and God the soul."

Others study nature and her plans as we see them developed on the surface of this little planet which we inhabit; the astronomer would fain learn the plan on which the whole universe is constructed. The magnificent conception of Copernicus is, for him, only an introduction to the yet more magnificent

conception of infinite space containing a collection of bodies which we call the visible universe. How far does this universe extend? What are the distances and arrangements of the stars? Does the universe constitute a system? If so, can we comprehend the plan on which this system is formed, of its beginning and of its end? Has it bounds outside of which nothing exists but the black and starless depths of infinity itself? Or are the stars we see simply such members of an infinite collection as happen to be the nearest our system? A few such questions as these we are perhaps beginning to answer; but hundreds, thousands, perhaps even millions of years may elapse without our reaching a complete solution. Yet the astronomer does not view them as Kantian antinomies, in the nature of things insoluble, but as questions to which he may hopefully look for at least a partial answer.

The problem of the distances of the stars is of peculiar interest in connection with the Copernican system. The greatest objection to this system, which must have been more clearly seen by astronomers themselves than by any others, was found in the absence of any apparent parallax of the stars. If the earth performed such an immeasurable circle around the sun as Copernicus maintained, then, as it passed from side to side of its orbit, the stars outside the solar system must appear to have a corresponding motion in the other direction, and thus to swing back and forth as the earth moved in one and the other direction. The fact that not the slightest swing of that sort could be seen was, from the time of Ptolemy, the basis on which the doctrine of the earth's immobility rested. The difficulty was simply ignored by Copernicus and his immediate successors. The idea that nature would not squander space by allowing immeasurable stretches of it to go unused seems to have been one from which mediæval thinkers could not entirely break away. The consideration that there could be no need of any such economy, because the supply was infinite, might have been theoretically acknowledged, but was not practically felt. The fact is that magnificent as was the conception of Copernicus, it was dwarfed by the conception of stretches from star to star

so vast that the whole orbit of the earth was only a point in comparison.

An indication of the extent to which the difficulty thus arising was felt is seen in the title of a book published by Horrebow, the Danish astronomer, some two centuries ago. This industrious observer, one of the first who used an instrument resembling our meridian transit of the present day, determined to see if he could find the parallax of the stars by observing the intervals at which a pair of stars in opposite quarters of the heavens crossed his meridian at opposite seasons of the year. When, as he thought, he had won success, he published his observations and conclusions under the title of Copernicus Triumphans. But alas! the keen criticism of his contemporaries showed that what he supposed to be a swing of the stars from season to season arose from a minute variation in the rate of his clock, due to the different temperatures to which it was exposed during the day and the night. The measurement of the distance even of the nearest stars evaded astronomical research until Bessel and Struve arose in the early part of the present century.

On some aspects of the problem of the extent of the universe light is being thrown even now. Evidence is gradually accumulating which points to the probability that the successive orders of smaller and smaller stars, which our continually increasing telescopic power brings into view, are not situated at greater and greater distances, but that we actually see the boundary of our universe. This indication lends a peculiar interest to various questions growing out of the motions of the stars. Quite possibly the problem of these motions will be the great one of the future astronomer. Even now it suggests thoughts and questions of the most far-reaching character.

I have seldom felt a more delicious sense of repose than when crossing the ocean during the summer months I sought a place where I could lie alone on the deck, look up at the constellations, with Lyra near the zenith, and, while listening to the clank of the engine, try to calculate the hundreds of millions of years which would be required by our ship to reach the star α Lyræ if she could continue her course in that direction with-

out ever stopping. It is a striking example of how easily we may fail to realize our knowledge when I say that I have thought many a time how deliciously one might pass those hundred millions of years in a journey to the star α Lyræ, without its occurring to me that we are actually making that very journey at a speed compared with which the motion of a steamship is slow indeed. Through every year, every hour, every minute, of human history from the first appearance of man on the earth, from the era of the builders of the Pyramids, through the times of Cæsar and Hannibal, through the period of every event that history records, not merely our earth, but the sun and the whole solar system with it, have been speeding their way toward the star of which I speak on a journey of which we know neither the beginning nor the end. During every clock beat through which humanity has existed it has moved on this journey by an amount which we can not specify more exactly than to say that it is probably between 5 and 9 miles per second. We are at this moment thousands of miles nearer to α Lyræ than we were a few minutes ago when I began this discourse, and through every future moment, for untold thousands of years to come, the earth and all there is on it will be nearer to α Lyræ, or nearer to the place where that star now is, by hundreds of miles for every minute of time come and gone. When shall we get there? Probably in less than a million years, perhaps in half a million. We can not tell exactly, but get there we must if the laws of nature and the laws of motion continue as they are. To attain to the stars was the seemingly vain wish of the philosopher, but the whole human race is, in a certain sense, realizing this wish as rapidly as a speed of 6 or 8 miles a second can bring it about.

I have called attention to this motion because it may, in the not distant future, afford the means of approximating to a solution of the problem already mentioned—that of the extent of the universe. Notwithstanding the success of astronomers during the present century in measuring the parallax of a number of stars, the most recent investigations show that there are very few, perhaps hardly more than a score, of stars of which

the parallax, and therefore the distance, has been determined with any approach to certainty. Many parallaxes determined by observers about the middle of the century have had to disappear before the powerful tests applied by measures with the heliometer; others have been greatly reduced and the distances of the stars increased in proportion. So far as measurement goes, we can only say of the distances of all the stars, except the few whose parallaxes have been determined, that they are immeasurable. The radius of the earth's orbit, a line more than ninety millions of miles in length, not only vanishes from sight before we reach the distance of the great mass of stars, but becomes such a mere point that when magnified by the powerful instruments of modern times the most delicate appliances fail to make it measurable. Here the solar motion comes to our help. This motion, by which, as I have said, we are carried unceasingly through space, is made evident by a motion of most of the stars in the opposite direction, just as passing through a country on a railway we see the houses on the right and on the left being left behind us. It is clear enough that the apparent motion will be more rapid the nearer the object. We may therefore form some idea of the distance of the stars when we know the amount of the motion. It is found that in the great mass of stars of the sixth magnitude, the smallest visible to the naked eye, the motion is about three seconds per century. As a measure thus stated does not convey an accurate conception of magnitude to one not practiced in the subject, I would say that in the heavens, to the ordinary eye, a pair of stars will appear single unless they are separated by a distance of 150 or 200 seconds. Let us, then, imagine ourselves looking at a star of the sixth magnitude, which is at rest while we are carried past it with the motion of 6 or 8 miles per second which I have described. Mark its position in the heavens as we see it to-day; then let its position again be marked 5,000 years hence. A good eye will just be able to perceive that there are two stars marked instead of one. The two would be so close together that no distinct space between them could be perceived by unaided vision. It is due to the magnifying power

of the telescope, enlarging such small apparent distances, that the motion has been determined in so small a period as the 150 years during which accurate observations of the stars have been made.

The motion just described has been fairly well determined for what, astronomically speaking, are the brighter stars; that is to say, those visible to the naked eye. But how is it with the millions of faint telescopic stars, especially those which form the cloud masses of the Milky Way? The distance of these stars is undoubtedly greater, and the apparent motion is therefore smaller. Accurate observations upon such stars have been commenced only recently, so that we have not yet had time to determine the amount of the motion. But the indication seems to be that it will prove quite a measurable quantity and that before the twentieth century has elapsed it will be determined for very much smaller stars than those which have heretofore been studied. A photographic chart of the whole heavens is now being constructed by an association of observatories in some of the leading countries of the world. I can not say all the leading countries, because then we should have to exclude our own, which, unhappily, has taken no part in this work. At the end of the twentieth century we may expect that the work will be repeated. Then, by comparing the charts, we shall see the effect of the solar motion and perhaps get new light upon the problem in question.

Closely connected with the problem of the extent of the universe is another which appears, for us, to be insoluble because it brings us face to face with infinity itself. We are familiar enough with eternity, or, let us say, the millions or hundreds of millions of years which geologists tell us must have passed while the crust of the earth was assuming its present form, our mountains being built, our rocks consolidated, and successive orders of animals coming and going. Hundreds of millions of years is indeed a long time, and yet, when we contemplate the changes supposed to have taken place during that time, we do not look out on eternity itself, which is veiled from our sight, as it were, by the unending succession of changes that mark the

progress of time. But in the motions of the stars we are brought face to face with eternity and infinity, covered by no veil whatever. It would be bold to speak dogmatically on a subject where the springs of being are so far hidden from mortal eyes as in the depths of the universe. But, without declaring its positive certainty, it must be said that the conclusion seems unavoidable that a number of stars are moving with a speed such that the attraction of all the bodies of the universe could never stop them. One such case is that of Arcturus, the bright reddish star familiar to mankind since the days of Job, and visible near the zenith on the clear evenings of May and June. Yet another case is that of a star known in astronomical nomenclature as 1830 Groombridge, which exceeds all others in its angular proper motion as seen from the earth. We should naturally suppose that it seems to move so fast because it is near us. But the best measurements of its parallax seem to show that it can scarcely be less than two million times the distance of the earth from the sun, while it may be much greater. Accepting this result, its velocity can not be much less than 200 miles per second, and may be much more. With this speed it would make the circuit of our globe in two minutes, and had it gone round and round in our latitudes we should have seen it fly past us a number of times since I commenced this discourse. It would make the journey from the earth to the sun in five days. If it is now near the center of our system it would probably reach its confines in a million of years. So far as our knowledge of nature goes, there is no force in nature which would ever have set it in motion and no force which can ever stop it. What, then, was the history of this star, and, if there are planets circulating around, what the experience of beings who may have lived on those planets during the ages which geologists and naturalists assure us our earth has existed? Did they see at night only a black and starless heaven? Was there a time when in that heaven a small faint patch of light began gradually to appear? Did that patch of light grow larger and larger as million after million of years elapsed? Did it at last fill the heavens and break up into constellations as we now see them?

As millions more of years elapse will the constellations gather together in the opposite quarter and gradually diminish to a patch of light as the star pursues its irresistible course of 200 miles per second through the wilderness of space, leaving our universe farther and farther behind it, until it is lost in the distance? If the conceptions of modern science are to be considered as good for all time—a point on which I confess to a large measure of scepticism—then these questions must be answered in the affirmative.

Intimately associated with these problems is that of the duration of the universe in time. The modern discovery of the conservation of energy has raised the question of the period during which our sun has existed and may continue in the future to give us light and heat. Modern science tells us that the quantity of light and heat which can be stored in it is necessarily limited, and that, when radiated as the sun radiates, the supply must in time be exhausted. A very simple calculation shows that were there no source of supply the sun would be cooled off in three or four thousand years. Whence, then, comes the supply? During the past thirty years the source has been sought for in a hypothetical contraction of the sun itself. True, this contraction is too small to be observed. Several thousand years must elapse before it can be measurable with our instruments. Granting that this is and always has been the sole source of supply, a simple calculation shows that the sun could scarcely have been giving its present amount of heat for more than twenty or thirty millions of years. Before that time the earth and the sun must have formed one body, a great nebula, by the condensation of which both are supposed to have been formed. But the geologists tell us that the age of the earth is to be reckoned by hundreds of millions of years. Thus arises a question to which physical science has not been able to give an answer.

The problems of which I have so far spoken are those of what may be called the older astronomy. If I apply this title it is because that branch of the science to which the spectroscope has given birth is often called the new astronomy. It is commonly to be expected that a new and vigorous form of scientific

research will supersede that which is hoary with antiquity. But I am not willing to admit that such is the case with the old astronomy, if old we may call it. It is more pregnant with future discoveries to-day than it ever has been, and it is more disposed to welcome the spectroscope as a useful handmaid, which may help it on to new fields, than it is to give way to it. How useful it may thus become has been recently shown by a Dutch astronomer, who finds that the stars having one type of spectrum belong mostly to the Milky Way, and are farther from us than the others.

In the field of the newer astronomy perhaps the most interesting work is that associated with comets. It must be confessed, however, that the spectroscope has rather increased than diminished the mystery which, in some respects, surrounds the constitution of these bodies. The older astronomy has satisfactorily accounted for their appearance, and we might also say for their origin and their end, so far as questions of origin can come into the domain of science. It is now known that comets are not wanderers through the celestial spaces from star to star, but must always have belonged to our system. But their orbits are so very elongated that thousands, or even hundreds of thousands, of years are required for a revolution. Sometimes, however, a comet passing near to Jupiter is so fascinated by that planet that, in its vain attempts to follow it, it loses so much of its primitive velocity as to circulate around the sun in a period of a few years, and thus to become, apparently, a new member of our system. If the orbit of such a comet, or in fact of any comet, chances to intersect that of the earth, the latter in passing the point of intersection encounters minute particles which causes a meteoric shower. The great showers of November, which occur three times in a century and were well known in the years 1866–67, may be expected to reappear about 1900, after the passage of a comet which, since 1866, has been visiting the confines of our system, and is expected to return about two years hence.

But all this does not tell us much about the nature and make-up of a comet. Does it consist of nothing but isolated

particles, or is there a solid nucleus, the attraction of which tends to keep the mass together? No one yet knows. The spectroscope, if we interpret its indications in the usual way, tells us that a comet is simply a mass of hydrocarbon vapor, shining by its own light. But there must be something wrong in this interpretation. That the light is reflected sunlight seems to follow necessarily from the increased brilliancy of the comet as it approaches the sun and its disappearance as it passes away.

Great attention has recently been bestowed upon the physical constitution of the planets and the changes which the surfaces of those bodies may undergo. In this department of research we must feel gratified by the energy of our countrymen who have entered upon it. Should I seek to even mention all the results thus made known I might be stepping on dangerous ground, as many questions are still unsettled. While every astronomer has entertained the highest admiration for the energy and enthusiasm shown by Mr. Percival Lowell in founding an observatory in regions where the planets can be studied under the most favorable conditions, they can not lose sight of the fact that the ablest and most experienced observers are liable to error when they attempt to delineate the features of a body 50,000,000 or 100,000,000 miles away through such a disturbing medium as our atmosphere. Even on such a subject as the canals of Mars doubts may still well be felt. That certain markings to which Schiaparelli gave the name of canals exist, few will question. But it may be questioned whether these markings are the fine, sharp, uniform lines found on Schiaparelli's map and delineated in Mr. Lowell's beautiful book. It is certainly curious that Barnard at Mount Hamilton, with the most powerful instrument and under the most favorable circumstances, does not see these markings as canals.

I can only mention among the problems of the spectroscope the elegant and remarkable solution of the mystery surrounding the rings of Saturn, which has been effected by Keeler at Allegheny. That these rings could not be solid has long been a conclusion of the laws of mechanics, but Keeler was the first

to show that they must consist of separate particles, because the inner portions revolve more rapidly than the outer. The question of the atmosphere of Mars has also received an important advance by the work of Campbell at Mount Hamilton. Although it is not proved that Mars has no atmosphere, for the existence of some atmosphere can scarcely be doubted, yet the Mount Hamilton astronomer seems to have shown, with great conclusiveness, that it is so rare as not to produce any sensible absorption of the solar rays.

I have left an important subject for the close. It belongs entirely to the older astronomy, and it is one with which I am glad to say this observatory is expected to especially concern itself. I refer to the question of the variation of latitudes, that singular phenomenon scarcely suspected ten years ago, but brought out by observations in Germany during the past eight years, and reduced to law with such brilliant success by our own Chandler. The North Pole is not a fixed point on the earth's surface, but moves around in rather an irregular way. True, the motion is small; a circle of 60 feet in diameter will include the pole in its widest range. This is a very small matter so far as the interests of daily life are concerned; but it is very important to the astronomer. It is not simply a motion of the pole of the earth, but a wabbling of the solid earth itself. No one knows what conclusions of importance to our race may yet follow from a study of the stupendous forces necessary to produce even this slight motion.

The director of this new observatory has already distinguished himself in the delicate and difficult work of investigating this motion, and I am glad to know that he is continuing the work here with one of the finest instruments ever used in it, a splendid product of American mechanical genius. I can assure you that astronomers the world over will look with the greatest interest for Professor Doolittle's success in the arduous task he has undertaken.

There is one question connected with these studies of the universe on which I have not touched, and which is, nevertheless, of transcendent interest. What sort of life, spiritual and

intellectual, exists in distant worlds? We can not for a moment suppose that our little planet is the only one throughout the whole universe on which may be found the fruits of civilization, warm firesides, friendship, the desire to penetrate the mysteries of creation. And yet this question is not to-day a problem of astronomy, nor can we see any prospect that it ever will be, for the simple reason that science affords us no hope of an answer to any question that we may send through the fathomless abyss. When the spectroscope was in its infancy it was suggested that possibly some difference might be found in the rays reflected from living matter, especially from vegetation, that might enable us to distinguish them from rays reflected by matter not endowed with life. But this hope has not been realized, nor does it seem possible to realize it. The astronomer can not afford to waste his energies on hopeless speculation about matters of which he can not learn anything, and he therefore leaves this question of the plurality of worlds to others who are as competent to discuss it as he is. All he can tell the world is:

> He who through vast immensity can pierce,
> See worlds on worlds compose one universe;
> Observe how system into system runs,
> What other planets circle other suns,
> What varied being peoples every star,
> May tell why Heaven has made us as we are.

QUESTIONS AND EXERCISES

This selection is an example of the brief review of a number of problems in some particular field.

1. How many problems of astronomy has Newcomb discussed? Upon what principle does he seem to have chosen these—importance, popular interest, or what?

2. In what order does he take these problems up?

3. Does he merely state each problem in such detail as to make it clear, or does he show the possible solution of it?

4. Examine carefully the comparisons, analogies, concrete illustrations and in making intelligible astronomical distances, rates of motions, etc.

Exercise 1. Review, after the manner of Newcomb in this selection, some of the unsolved problems in chemistry, physics, bacteriology, or some other science with which you are familiar.

Exercise 2. Point out some of the problems and difficulties connected with one of the following:

Spelling reform.
Conservation of natural resources.
Regulation of interstate commerce.
Accumulation of wealth.
The industrial status of woman.
College discipline.
City school systems.
Military ballooning.
Distribution of wealth.
Government ownership of railways, telegraphs, etc.

METHODS OF COMPILATION

THE PROCESSES OF LIFE REVEALED BY THE MICROSCOPE[1]

SIMON HENRY GAGE

IT is characteristic of the races of men that almost at the dawn of reflection the first question that presses for solution is this one of life—life as manifested in men and in the animals and plants around them. What and whence is it, and whither does it tend? Then the sky with its stars, the earth with its sunshine and storm, light and darkness, stand out like great mountain peaks demanding explanation. So in the life of every human being, repeating the history of his race, as the evolutionists are so fond of saying, the fundamental questions are first to obtrude themselves upon the growing intelligence. There is no waiting, no delay for trifling with the simpler problems; the most fundamental and most comprehensive come immediately to the fore and alone seem worthy of consideration. But as age advances most men learn to ignore the fundamental questions and to satisfy themselves with simpler and more secondary matters, as if the great realities were all understood or nonexistent. No doubt to many a parent engaged in the affairs of society, politics, finance, science, or art, the questions that their children put, like drawing aside a thick curtain, bring into view the fundamental questions, the great realities; and we know again that what is absorbing the power and attention of our mature intellect, what perhaps in pride we feel a mastery over, are only secondary matters after all, and to the great

[1] Reprinted from *Transactions* of the American Microscopical Society, Vol. 17, 1896, page 3, by permission of the author.

questions of our own youth, repeated with such earnestness by our children, we must confess with humility that we still have no certain answers. It behooves us, then, if the main questions of philosophy and science can not be answered at once, to attempt a more modest task, and by studying the individual factors of the problem to hope ultimately to put these together and thus gain some just comprehension of the entire problem.

This address is, therefore, to deal, not with life itself, but with some of the processes or phenomena which accompany its manifestations. But it is practically impossible to do fruitful work according to the Baconian guide of piling observation on observation. This is very liable to be a dead mass, devoid of the breath of life. It is a well-known fact that the author of the Novum Organum, the key which Bacon supposed would serve as the open sesame of all difficulties and yield certain knowledge, this potent key did not unlock many of the mysteries of science for its inventor. Every truly scientific man since the world began has recognized the necessity of accurate observation, and no scientific principle has ever yet been discovered simply by speculation; but every one who has really unlocked any of the mysteries of nature has inspired, made alive his observations by the imagination; he has, as Tyndall so well put it, made a scientific use of the imagination and created for himself what is known as the "working hypothesis." It must be confessed that for some investigators the "hypothesis" becomes so dear that if the facts of nature do not conform to the hypothesis, "so much the worse for the facts." But for the truly scientific man the hypothesis is destined solely to enable him to get the facts of nature in some definite order, an order which shall make apparent their connection with the great order and harmony which is believed to be present in the universe.

If the working hypothesis fails in any essential particular, he is ready to modify or discard it. For the truly inspired investigator one undoubted fact weighs more in the balance than a thousand theories.

At the very threshold of any working hypothesis for the

biologist, this question as to the nature of the energy we call life must be considered. The great problem must receive some kind of a hypothetical solution. What is its relation to the energies of light, heat, electricity, chemism, and the other forms discussed by the physicist? Are its complex manifestations due only to these, or does it have a character and individuality of its own? If we accept the ordinarily received view of the evolution of our solar system, the original fiery nebula, in which heat reigned supreme, slowly dissipated part of its heat, and hurled into space the planets, themselves flaming vapors, only the protons of the solid planets. As the heat became further dissipated there appeared in the cooling mass manifestations of chemical attraction, compounds, at first gases, then liquids, and finally, on the cooling planets, solids appeared. Lastly upon our own planet, the earth, when the solid crust was formed and the temperature had fallen below the boiling point of water, the seas were formed and then life appeared. Who could see, in the incandescent nebula, the liquids and solids of our planet and the play upon them of chemism, of light, heat, electricity, cohesion, tension, and the other manifestations so familiar to all? And yet, who is there that for a moment believes that aught of matter or energy was created in the different stages of the evolution? They appeared or were manifested just as soon as the conditions made it possible. So it seems to me that the energy called life manifested itself upon this planet when the conditions made it possible, and it will cease to manifest itself just as soon as the conditions become sufficiently unfavorable. It was the last of the forms of energy to appear upon this planet and it will be the first to disappear.

In brief, it seems to me that the present state of physical and physiological knowledge warrants the assumption, the working hypothesis, that life is a form of energy different from those considered in the domain of physics and chemistry. This form of energy is the last to appear, last because more conditions were necessary for its manifestations. It, like the other forms of energy, requires a material vehicle through which to act, but the results produced by it are vastly more complex. Like

the other energies of nature, it does not act alone. It acts with the energies of the physicist, but as the master; and under its influence the manifestations pass infinitely beyond the point where for the ordinary energies of nature it is written "thus far and no farther."

It can be stated without fear of refutation that every physiological investigation shows with accumulating emphasis that the manifestations of living matter are not explicable with only the forces of dead matter, and the more profound the knowledge of the investigator the more certain is the testimony that the life energy is not a mere name. And, strange to say, the physicist and the chemist are most emphatic in declaring that life is an energy outside their domain.

The statements of a chemist, a physicist, and a biologist are added. From the character and attainments of these men their testimony, given after years of the most earnest investigation and reflection, is worthy of consideration.

When a celebrated chemist was asked if he believed that a leaf or a flower could be formed or could grow by chemical forces, he answered:

"I would more readily believe that a book on chemistry or on botany could grow out of dead matter by chemical processes."—LIEBIG.

"The influence of animal or vegetable life on matter is infinitely beyond the range of any scientific inquiry hitherto entered on. Its power of directing the motions of moving particles, in the demonstrated daily miracle of our human free will, and in the growth of generation after generation of plants from a single seed, are infinitely different from any possible result of the fortuitous concourse of atoms; and the fortuitous concourse of atoms is the sole foundation in philosophy on which can be founded the doctrine that it is impossible to derive mechanical effect from heat otherwise than by taking heat from a body at a higher temperature, converting at most a definite proportion of it into mechanical effect, and giving out the whole residue to matter at a lower temperature."—SIR WILLIAM THOMSON (LORD KELVIN).

"The anagenetic [vital] energy transforms the face of nature by its power of assimilating and recompounding inorganic matter, and by its capacity for multiplying its individuals. In spite of the mechanical destructibility of its physical basis (protoplasm) and the ease with which its mechanisms are destroyed, it successfully resists, controls, and remodels the catagenetic [physical and chemical] energies for its purpose."—Cope.

What, then, are the manifestations of the life energy? and what are the processes which are discernible? All of us, in whatever walk of life, will recognize the saying of Gould:

"Now, when one looks about him the plainest, largest fact he sees is that of the distinction between living and lifeless things."

As life goes on and works with power where the unaided eye fails to detect it, the microscope—marvelous product of the life energy in the brain of man—shows some of these hidden processes. It has done for the infinitely little on the earth what the telescope has done for the infinitely great in the sky.

Let us commence with the little and the simple. If a drop of water from an aquarium, stream, or pool is put under the microscope many things appear. It is a little world that one looks into, and like the greater one that meets our eye on the streets, some things seem alive and some lifeless. As we look we shall probably find, as in the great world, that the most showy is liable in the end to be the least interesting. In the microscope world there will probably appear one or more small rounded masses which are almost colorless. If one of these is watched, lo! it moves, not by walking or swimming, but by streaming itself in the direction. First a slender or blunt knob appears, then into it all of the rest of the mass moves, and thus it has changed its position. If the observation is continued, this living speck, which is called an amœba, will be seen to approach some object and retreat, indeed, it comports itself as if sensitive, with likes and dislikes. If any object suitable for food is met in its wanderings the living substance flows around it, engulfs it and dissolves the nutrient portions and

turns them into its own living substance; the lifeless has been rendered alive. If the eye follows the speck of living matter the marvels do not cease. After it has grown to a certain size, as if by an invisible string, it constricts itself in the middle and finally cuts itself in two. The original amœba is no more, in its place there are two. Thus nearly at the bottom of the scale of life are manifested all of the fundamental features—the living substance moves itself, takes nourishment, digests it and changes nonliving into living substance and increases in size; it seems to feel and to avoid the disagreeable and choose the agreeable, and finally it performs the miracle of reproducing its kind, of giving out its life and substance to form other beings, its offspring.

It is the belief of many biologists that the larger and complex forms, even up to man himself, may be considered an aggregation of structural elements originally more or less like the amœba just described; but instead of each member of the colony, each individual itself carrying on all the processes of life independently, as with the amœba, there is a division of labor. Some move, some digest, some feel, think, and choose, some give rise to new beings, all change lifeless matter into their own living substance.

The processes and phenomena by which a new individual is produced are included under the comprehensive term embryology.

All organisms, great or small, are but developments of minute germs budded off by the parent or parents, and the way in which these minute beginnings develop into perfect forms like their parents can only be followed by the aid of a microscope. Indeed, in no field of biology has the microscope done such signal service in revealing the processes of life.

The method of the production of a new being with the amœba, as we have just seen, is for the parent to give itself entire to its offspring—the parent ceasing to be in producing its offspring. With some other lowly forms a part of the body of the parent buds out, grows, and finally falls off as an independent organism or remains connected with the parent to form a colony. In

the vegetable world a familiar example of a colony is represented by the plant that the children call "old hen and chickens."

In the higher animals, however, where specialization is carried to its extreme limit, some myriads of cells forming the body are set apart to produce motion, others digest food, still others think and feel, while comparatively few, the germ cells, are destined for the continuation of the race. In the higher and highest forms especially, all observation goes to show that the life energy, not satisfied with the mere vitalization of matter and a dead level of excellence, is aiming at perpetual ascent, greater mastery over matter and its physical forces. For the more certain attainment of this end, the production of offspring is no longer possible for one individual; two wholly separate individuals must join, each contributing its share of the living matter which is to develop into a new being. In this way the accumulated acquirements of two are united with the consequent increase in the tendencies and impulses for modification and nearly double the protection for the offspring. Thus, in striking contrast to the amœba, where the single parent gives all of itself to form offspring and in so doing disappears and loses its identity, in the higher forms, while two must unite to form the offspring, the parents remain and retain their individuality and the ability to produce still other offspring. The process by which this is accomplished may be traced step by step with the microscope. A germ cell of the father and one of the mother fuse together, and from this new procreative cell formed by the fusion of two, with all their possibilities combined, the new individual arises. This certain knowledge is the result of the profound investigation of the last few years, and shows the literalness of the Scriptural statement, "they shall be one flesh."

After this fusion of the father and mother germ cells the single cell thus formed, like the amœba, divides into two, and these into four and so on, but unlike the amœba all the cells remain together. Within this cellular mass, as if by an unseen builder, the cells are deftly arranged in their place, some to form brain, some heart, some the digestive tract, others for movement; so that finally from the simple mass of cells, originally so alike, arises

the complex organism, fish or bird, beast or man. How perfectly the word "offspring" describes the life process in the production of this new being! That the child should resemble both father and mother is thus made intelligible, for it is a part of both. Yes, further, it may resemble grandfather or great grandfather or mother, for truly it is a part of them, their life conserved and continued. There is no new life, it is only a continuation of the old. "Omne vivum ex vivo," all life from life. But the demonstration of this prime fact required a microscope, and it is an achievement of the last half of this century. How counter this statement still is to the common belief of mankind we may perhaps better appreciate if we recall our own youth, and remember with what absolute confidence we expected the stray horsehairs we had collected and placed in water to turn into living snakes.[1] The belief that it is an everyday occurrence for living beings to arise from lifeless matter was not by any means confined to those uneducated in biology. It was held by many scientific men within the memory of most of us. Indeed this goblin of spontaneous generation, even for the scientific world, has been laid low so recently that the smoke of battle has scarcely yet cleared from the horizon.

In the complex body of animals, as stated above, the constituent elements perform different functions. Is there any hint of the way in which the action is accomplished? Let us glance at two systems, the nervous and the glandular, widely different in structure and function. All know how constantly the glands are called into requisition, the salivary glands for saliva, those of the stomach and the pancreas for their digestive

[1] Reference is here made to the nematoid worm *Gordius*. This worm lives a part of its life as a parasite in the larvæ of aquatic insects and in some fish. In the adult free condition it differs markedly from the larval, parasitic stage, and is very slender and much elongated, often reaching a length of 20 to 30 centimeters (8 to 10 inches), and has the general appearance of a coarse hair like that from the tail of a horse. It lives in water and in wet places, and frequently appears in horse troughs and the wet places where the trough overflows. From the hair-like appearance it was and still is believed that a hair from the horse's tail or mane had directly transformed into a living creature. By many persons it is called a hair snake, by others a hair worm. Often one or several become tangled in an almost inextricable knot, whence the name from the famous "Gordian knot."

juices, etc. If we take now the pancreas as an example, and that of a living, fasting animal is put under the microscope so that its constituent cells can be observed, it will be seen that they are clouded, their outlines and that of their nuclei being vague and indistinct. The cell is apparently full of coarse grains. If now the animal is fed, as the digestion proceeds the pancreas pours out its juice. At the same time the granules, and with them the cloudiness, gradually disappear, the cells become clear, and both they and their nuclei are sharply outlined. That is, the substance which is to form the pancreatic juice is stored in the cells in the form of granules during the periods of rest, and held until the digestive agent is demanded, and if the demand is great all the granules may be used up. But as soon as the demand ceases the cells begin again their special vital action, and again the granules begin to appear and increase in number until finally the cells become so full that they are fully charged and again ready to pour forth the digestive fluid. This is a daily, almost an hourly process.

Let us take another example in which it would almost appear that there is organic memory on the part of the gland cells. No doubt all have seen the clear jelly-like masses surrounding the eggs of frogs and salamanders. Whence comes this jelly that is so resistant to the agents that work so quickly the destruction of ordinary organic matter? As spring advances the cells of the oviduct increase enormously in size. The microscope shows this increase to be due to a multitude of clear granules. As the eggs move along, the ova are coated with the jelly formed from the granules given out by the cells. As this material for the jelly is poured out the cells gradually shrink to their original size, and then wait another twelve months before doing their destined work.

If one can thus catch a glimpse of some of the finer processes taking place in gland action, how is it with nervous action, the highest function of which living matter is capable? While it has been known for a long time that the nervous system is the organ of thought and feeling and the director and coördinator of the motions of the body, and many speculations had been

made concerning the processes through which the nervous tissue passes in performing its functions, it was left to an American student, Dr. Hodge, to first successfully show that there were visible changes through which the nervous system passes in its work. The question is, can the activity of the nervous system be traced as surely by changes occurring in the living matter forming its basis, as the action of a gland can be seen by the study of the gland cells?

The demonstration is simple now that the method has been shown. No doubt everyone has had the experience of failing to perform some difficult muscular action at one time and then at another of doing it with ease, or of finding true the reverse of the adage, "practice makes perfect." For example, in a trial of skill, as in learning to ride a bicycle, all the complicated action may be performed with considerable ease and certainty at the beginning of a lesson, when one is fresh, but as the practice continues the results become progressively less and less successful, and finally with increasing weariness there is only failure, and one must rest. We say the muscles are tired. This is true in part, but of much greater importance is the fatigue of the nervous system, as this furnishes the impulses for the action and coördination of the muscles. Now, as muscular action can be seen and the amount can be carefully controlled, here was an exact indicator of the time and amount of the nervous activity. Furthermore, as animals have two similar sides, one arm or leg may work and the other remain at rest, and consequently corresponding sides of the nervous system may be active and at rest. By means of electrical irritation one arm of a cat or other animal was caused to move vigorously for a considerable time, the other arm remaining at rest. Then the two sides of the nervous system—that is, the pairs of nerves to the arms with their ganglia and a segment of the myel (spinal cord)—were removed and treated with fixing agents, and carried through all the processes necessary to get thin sections capable of accurate study with the microscope. Finally upon the same glass slide are parts of the nervous system fatigued even to exhaustion, and corresponding parts of the same

animal which had been at rest. Certainly if the nervous substance shows the result or processes of its action the conditions are here perfect. Fatigued nerve cells are side by side with those in a state of rest. The appearances are clear and unmistakable. The nucleus has markedly decreased in size in the fatigued cells and possesses a jagged, irregular outline in place of the smooth, rounded form of the resting cells. The cell substance is shrunken in size and possesses clear, scattered spaces, or a large, clear space around the nucleus.

If the nervous substance was not fixed at once but remained in the living animal for twelve to twenty-four hours in a state of repose, the signs of exhaustion disappeared and the two sides appeared alike. By studying preparations made after various periods of repose all the stages of recovery from exhaustion could be followed.

For possible changes in normal fatigue, sparrows, pigeons, and swallows, and also honeybees, were used. For example, if two sparrows or two honeybees as nearly alike as possible were selected, the nervous system of one being fixed in the morning after the night's rest and that of the other after a day of toil, the changes in the cells of the brain of the honeybee or sparrow and in the spinal ganglia of the sparrow were as marked as in case of artificial fatigue. After prolonged rest, then, the nerve cells are, so to speak, charged; they are full and ready for labor; but after a hard day's work they are discharged—shrunken and exhausted.

There is one more step in this brilliant investigation. If in the morning, after sleep and rest, animals and men are full of vigor, and in the evening are weary and exhausted, how like is it to the beginning and end of life? In youth so overflowing with vigor that to move, to act, is pleasure, and continued rest a pain; but in the evening of life a warm corner and repose are what we try to furnish those whose work is done. How is this correlated in the cells of the nervous system with the states of rest and fatigue? With a well-nourished child which died from one of the accidents of birth the nerve cells showed all the characters of cells at rest and fully charged. In a man dying naturally of old age the cells showed the shrunken nuclei and

all the appearances of exhausting fatigue. In the one was the potentiality of a life of vigorous action; the other showed the final fatigue—the store of life energy had been dissipated, and there was no recovery possible.

For the animals that possess an undoubted nervous system probably all would admit that there is some sort of nervous action corresponding to sensation; but what of living matter in the humbler forms where no nervous system can be found? That these have vital motion, that they breathe, nourish themselves, grow, and produce offspring, none can deny. Do they have anything comparable with sensation? As most of the lowest forms are minute, the microscope comes to our aid again, and in watching these lowliest living beings it is found that they discriminate and choose, going freely into some portions of their liquid world and withdrawing from other portions. If some drug which is unusual or we must believe disagreeable is added to a part of the water, they withdraw from that part. It seems to have the same effect as disagreeable odors on men and animals. On the other hand, there are substances which attract, and into the water containing these they enter with eagerness. Strange is it, too, that, as proved by experiment, if an unattractive substance is used and also one on the other side that has been found still more unattractive, the less disagreeable is selected; the less of the two evils is chosen.

As man, the horse, dog, and many other animals adapt themselves gradually to temperatures either very cold or very warm, and that, too, by a change in their heat-regulating power rather than by a change of hairy or other clothing, so these lowly organisms are found in nature in water at temperatures from near freezing up to 60° or 80° C., a point approaching that of boiling water. It may be answered that each was created for its place, but by means of a microscope and a delicate thermostat, to be certain of every step and to see all the results, Dr. Dallinger, through a period of seven years, accustomed the same unicellular organism and its progeny to variations of temperature from 15° to 20° C., *i. e.*, about the temperature of a comfortable sitting room, up to 70° C. For those at the cooler

temperature it was death to increase rapidly the heat 10°, and for those at the higher temperature it was equally fatal to lower it to the original temperature of 15° to 20°. These examples seem to show that it is one of the fundamental characteristics of living substance, whether in complex or simple forms, to adapt itself to its environment.

There is another fact in nature that the microscope has revealed and that fills the contemplative mind with wonder and an aspiration to see a little farther into the living substance, and so perchance discover the hidden springs of action. This fact may be called cellular altruism. In human society the philanthropist and soldier are ready at any time to sacrifice themselves for the race or the nation. With the animals the guards of the flock or herd are equally ready to die in its defense.

So within each of the higher organisms the microscope has shown a guarding host, the leucocytes or white-blood corpuscles. The brilliant discoveries in the processes of life with higher forms have shown that not only is there a struggle for existence with dead nature and against forms as large or larger than themselves, but each organism is liable to be undermined by living forms, animal and vegetable, infinitely smaller than themselves, insignificant and insidious, but deadly. Now, to guard the body against these living particles and the particles of dust that would tend to clog the system, there is a vast army of amœba-like cells, the leucocytes, that go wherever the body is attacked and do battle. If the guards succeed, the organism lives and flourishes; otherwise it dies or becomes weakened and hampered. This much was common scientific property three years ago, when one of our members (Miss Edith J. Claypole) came to my laboratory for advanced work. I discussed with her what has just been given and told her that there still remained to be solved the problem, What becomes of the clogging or deleterious material which the leucocytes have taken up? These body-guards are, after all, a part of the organism, and for them simply to engulf the material would not rid the body entirely of it, and finally an inevitable clogging of the system would result. The problem is simple and definite; what become of the dele-

terious substances, bacteria and dust particles, that get into the body and become engulfed by the leucocytes? Fortunately for the solution of this problem, in our beautiful Cayuga Lake there is an animal, the *Necturus*, with external gills through which the blood circulates for its purification. So thin and transparent is the covering tissue in these gills that one can see into the blood stream almost as easily as if it were uncovered. Every solid constituent of the blood, whether red corpuscle, white corpuscle, microbe, or particle of dust, can be seen almost as clearly as if mounted on a microscopic slide.

Into the veins of this animal was injected some lampblack, mixed with water, a little gum arabic and ordinary salt, an entirely nonpoisonous mixture. Thousands of particles of carbon were thus introduced into the blood and could be seen circulating with it through the transparent gills. True to their duty, the white corpuscles in a day or two engulfed the carbon particles, but for several days more the leucocytes could be seen circulating with the blood stream and carrying their load of coal with them. Gradually the carbon-laden corpuscles disappeared and only the ordinary carbon free ones remained. Where had the carbon been left? Had it been simply deposited somewhere in the system? The tissues were fixed and serial sections made. The natural pigment was bleached with hydrogen dioxid, so that if any carbon was present it would show unmistakably. With the exception of the spleen, no carbon appeared in the tissues, but in many places the carbon-laden leucocytes were found. In mucous cavities and on mucous surfaces and on the surface of the skin were many of them; in the walls of organs were many more apparently on their way to the surface with their load; that is, the carbon is actually carried out of the tissues upon the free surfaces of the skin and mucous membranes, where, being outside of the body, it could no more interfere in any way with it. But what is the fate of the leucocytes that carry the lampblack out of the tissues? They carry their load out and free the body, but they themselves perish. They sacrifice themselves for the rest of the body as surely as ever did soldier or philanthropist for the betterment or the preservation of the state.

Thus I have tried to sketch in briefest outline some of the phenomena or processes of life revealed by the microscope. Most of those discussed have come under my own personal observation, and are therefore to me particularly real and instructive; but to every one long familiar with the microscope and with the literature of biology many other examples will occur, some of them even more striking. The discussion has been confined to the above also because it seems to me to show with great clearness the way in which we can justifiably hope to do fruitful work in the future. This sure way, it seems to me, is the study of structure and function together; the function or activity serving as a clue and stimulus to the investigator for finding the mechanism through which function is manifested, and thus give due significance to structural details, which, without the hint from the function, might pass unnoticed.

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QUESTIONS AND EXERCISES

This selection will be used as the basis for some study of methods of gathering material from books. In all formal writing, systematic reference to sources of material is expected. This grows out of the spirit of thoroughness and fairness characteristic of the scientific attitude. It is part of thoroughness to exhibit the authorities upon which a discussion is based, showing these to be the fullest, latest, and most expert obtainable. It is part of fairness to show indebtedness to others for information. The two methods commonly used for making

such reference are (1) to scatter throughout the article detailed reference in footnotes giving authorities for statements made upon the page above, or (2) to place at the beginning or at the end of the article a bibliography, or list of books consulted. In the case of the present selection the second of these methods is used.

1. Does it seem to be the writer's intention to give all the sources of his information, or to mention only the most important? Is it his purpose to give support to his statements by authorities or to facilitate a reader's independent investigation of the subject by further reading? How has the writer made it possible for the reader, if he so desires, to prepare a fuller list of references? What is the value of the condensed comment under each item of the bibliography? Are such comments usual in bibliographies?

2. What besides books are included in the list?

3. Note that the items of the bibliography are arranged alphabetically under authors. Give reasons why this should be the customary form of arrangement. What other arrangements are possible and convenient?

4. How many parts are there to each item in the bibliography? Is there a uniform arrangement of these parts? Are they all necessary? Why, for example, the date? the page number?

5. In the second paragraph of the bibliography the writer indicates that it is best to begin the investigation of the subject with some general discussion. Why is it better to consult such books first in making the acquaintance of a subject than to start with some book giving detailed or specialized information?

Exercise 1. The first thing to do in gathering composition material from books and other printed sources is to prepare a bibliography. It is usually a waste of time to go to the library, and, with the first reference that comes to hand, begin to read and take notes. The investigator should first systematically find out just how large is the field of books on his particular subject. This he does by making at the start a bibliography of the accessible material. Any fairly large library may be expected to have the following helps to the preparation of such a list: (1) the card catalogue of the library by authors, titles, and subjects, arranged in alphabetical order in one list; (2) magazine indexes, such as Poole's and the *Readers' Guide to Periodical Literature*, *The Engineering Index*, Galloupe's *Index to Engineering Periodicals*, *International Catalogue of Scientific Literature*, *Technical Press Index;* (3) bibliographies found in books, such as Sonnenschein's *The Best Books* and *A Reader's Guide to Contemporary Literature*, Larned's

History for Ready Reference, and the standard encyclopedias which usually give at the close of each important article a list of authorities that may be consulted in further investigation of the subject.

By using the aids afforded by the library, prepare a bibliography for one of the following subjects, including as many items as possible:

Some general characteristics of the Philippines.

The place of physical culture in education.

The theory of cyclonic storms.

The Puritans of the time of Milton.

The income tax.

The place of manual training in higher education.

Student life in the University of Paris in the fourteenth century.

Possible abuses of hypnotic power.

The character and achievements of Huxley, Faraday, or some other noted scientist.

Any of the topics given in the lists on pages 258 and 272.

Exercise 2. The bibliography obtained by the methods suggested in the preceding exercise will likely be so large as to make it impossible to pursue the subject through every book on the list. The next step will therefore be the critical examination of the books in the bibliography to determine which will be most useful. Much in regard to the value of a book can be learned from its authorship. Determine whether it is by an authority. If it is not by a writer of recognized standing, it may be rejected in favor of some one with more standing. To find out about a writer of doubtful standing, consult encyclopedias, and such compilations as *Who's Who in America* for residents of the United States, and *Who's Who* for Englishmen and Canadians. Look also at the date. If the date is not recent, it is possible that later books and articles will serve the purpose better. Glance over the preface of the book to find the author's reasons for writing, the scope of the book, etc.—information that is likely to save a reader's time. From the table of contents ascertain the general plan and proportions of the book. If the investigation has proceeded some little way, and the investigator is looking up topics in detail, the index should be utilized.

In the case of the bibliography previously prepared, make a careful choice of the most suitable material for further consultation, following the hints given above.

Exercise 3. The bibliography having been secured, the next step is to gather from the books listed in it the material for the composition. Since in this part of the work poor methods and lack of system com-

monly cause waste of time, a few suggestions as to right methods are given. In reading for purposes of composition, every person has to assist his memory by note-taking. Notes should be taken on separate cards or slips of paper of uniform size. One point only should go in each card or slip. The notes should be few and brief. Each note should be accompanied by definite reference to the book and page, so that if the note proves too brief, the matter can be quickly looked up again. The notes should give the substance of the passage read, not in the words of the source, but in the words of the student. Such note-taking is not only excellent practice in condensation and conducive to thorough assimilation of reading, but it largely does away with the danger of "copying" when the time for composition comes. Such notes do not suggest the words of some one else; they leave the writer to choose freely his own phrasing. The ethics of the use of material from books is well summed up by Professor Charles Sears Baldwin in a paragraph in his *College Manual of Rhetoric*. "First, cite always; quote rarely; use phrase without quotation never. This last counsel ought to be superfluous; but from a confusion of too copious notes even educated people will make half conscious borrowings; and until this habit is broken nothing can be learned. Instead, then, of transcribing a passage to a note-book, note the point as briefly as possible, and the volume and page. This saves time, cultivates reflection, fixes the habit, necessary in all serious exposition of systematic reference. Facts are not copyrighted; but unless a writer is accepted as an authority, he is expected to tell where he found them. Form that is order, grouping, is private property, copyrighted. . . . Phrase is as strictly private as its maker's purse. It may, of course, be quoted, with citation as of fact; but frequent quotation is tiresome and unprofitable. Use without quotation is theft."

After the facts have been thus gathered, all is ready for the composing, or the "amplification," as it is sometimes called, of these notes into the finished composition. In this, the last stage of the process of compilation, the writer must call into play the cardinal principles of unity, emphasis, coherence, adaptability to a particular audience, etc., that have been studied in connection with other selections in this book.

Develop into a composition of about 1000 words the topic used in Exercises 1 and 2. Gather your material carefully and systematically according to the above suggestions.

EXTENDED AND SYSTEMATIC EXPLANATION OF A SINGLE IDEA

THE USEFULNESS OF EARTHQUAKES[1]

RICHARD A. PROCTOR

WE have lately had fearful evidence of the energy of the earth's internal forces.[2] A vibration which, when considered with reference to the dimensions of the earth's globe, may be spoken of as an indefinitely minute quivering limited to an insignificant area, has sufficed to destroy the cities and villages of whole provinces, to cause the death of thousands of human beings, and to effect a destruction of property which must be estimated by millions of pounds sterling. Such a catastrophe as this serves indeed to show how poor and weak a creature man is in presence of the grand workings of Nature. The mere throes which accompany her unseen subterranean efforts suffice to crumble man's strongest buildings in a moment into dust, while the unfortunate inhabitants are either crushed to death among the ruins, or forced to remain shuddering spectators of the destruction of their homes.

At first sight it may seem paradoxical to assert that earthquakes, fearfully destructive as they have so often proved, are yet essentially preservative and restorative phenomena; yet this is strictly the case. Had no earthquakes taken place in old times, man would not now be living on the face of the earth; if no earthquakes were to take place in future, the term of man's existence would be limited within a range of time far less than that to which it seems likely, in all probability, to be extended.

[1] Reprinted from *Light Science for Leisure Hours* (Longmans, Green, & Co.).
[2] Proctor refers to a disastrous earthquake in Peru in the year 1868.—ED.

If the solid substance of the earth formed a perfect sphere in ante-geologic times—that is, in ages preceding those to which our present geologic studies extend—there can be no doubt that there was then no visible land above the surface of the water; the ocean must have formed a uniformly deep covering to the submerged surface of the solid globe. In this state of things, nothing but the earth's subterranean forces could tend to the production of continents and islands. Let me be understood. I am not referring to the possibility or impossibility that lands and seas should suddenly have assumed their present figure without convulsion of any sort; this *might* have happened, since the Creator of all things can doubtless modify all things according to His will; I merely say that, assuming that in the beginning, as now, He permitted all things to work according to the laws He has appointed, then, undoubtedly, the submerged earth must have risen above the sea by the action of those very forms of force which produce the earthquake in our own times.

However this may be, it is quite certain that when once continents and lands had been formed, there immediately began a struggle between destructive and restorative (rather, perhaps, than preservative) forces.

The great enemy of the land is water, and water works the destruction of the land in two principal ways.

In the first place the sea tends to destroy the land by beating on its shores, and thus continually washing it away. It may seem at first sight that this process must necessarily be a slow one; in fact, many may be disposed to say that it is certainly a slow process, since we see that it does not alter the forms of continents and islands perceptibly in long intervals of time. But, as a matter of fact, we have never had an opportunity of estimating the full effects of this cause, since its action is continually being checked by the restorative forces we shall presently have to consider. Were it not thus checked, there can be little doubt that its effects would be cumulative; for the longer the process continued—that is, the more the land was beaten away—the higher would the sea rise, and the greater

power would it have to effect the destruction of the remaining land.

I proceed to give a few instances of the sea's power of effecting the rapid destruction of the land when nothing happens to interfere with the local action—premising, that this effect is altogether insignificant in comparison with that which would take place, even in that particular spot, if the sea's action were *everywhere* left unchecked.

The Shetland Isles are composed of substances which seem, of all others, best fitted to resist the disintegrating forces of the sea—namely, granite, gneiss, mica-slate, serpentine, greenstone, and many other forms of rock: yet, exposed as these islands are to the uncontrolled violence of the Atlantic Ocean, they are undergoing a process of destruction which, even within historical times, has produced very noteworthy changes. "Steep cliffs are hollowed out," says Sir Charles Lyell, "into deep caves and lofty arches; and almost every promontory ends in a cluster of rocks imitating the forms of columns, pinnacles, and obelisks." Speaking of one of the islands of this group, Dr. Hibbert says: "The isle of Stennes presents a scene of unequalled desolation. In stormy winters, large blocks of stone are overturned, or are removed from their native beds, and hurried to a distance almost incredible. In the winter of 1802, a tabular mass, eight feet two inches by seven feet, and five feet one inch thick, was dislodged from its bed, and carried to a distance of from eighty to ninety feet. In other parts of the Shetland Isles, where the sea has encountered less solid materials, the work of destruction has proceeded yet more effectively. In Roeness, for example, the sea has wrought its way so fiercely that a large cavernous aperture 250 feet long has been hollowed out. But the most sublime scene," says Dr. Hibbert, "is where a mural pile of porphyry, escaping the process of disintegration that is devastating the coast, appears to have been left as a sort of rampart against the inroads of the ocean. The Atlantic, when provoked by wintry gales, batters against it with all the force of real artillery; and the waves, in their repeated assaults, have at length forced for themselves

an entrance. This breach, named the Grind of the Navir, is widened every winter by the overwhelming surge that, finding a passage through it, separates large stones from its sides, and forces them to a distance of no less than 180 feet. In two or three spots, the fragments which have been detached are brought together in immense heaps, that appear as an accumulation of cubical masses, the product of some quarry."

Let us next turn to a portion of the coast-line of Great Britain which is neither defended, on the one hand, by barriers of rock, nor attacked, on the other, by the full fury of the Atlantic currents. Along the whole coast of Yorkshire we find evidences of a continual process of dilapidation. Between the projecting headland of Flamborough and Spurn Point (the coast of Holderness) the waste is particularly rapid. Many spots, which are now mere sandbanks, are marked in the old maps of Yorkshire as the sites of ancient towns and villages. Speaking of Hyde (one of these), Pennant says: "Only the tradition is left of this town." Owthorne and its church have been for the most part destroyed, as also Auburn, Hartburn, and Kilnsea. Mr. Phillips, in his "Geology of Yorkshire," states that not unreasonable fears are entertained that, at some future time, Spurn Point itself will become an island, or be wholly washed away, and then the ocean, entering into the estuary of the Humber, will cause great devastation. Pennant states that "several places, once towns of note upon the Humber, are now only recorded in history; and Ravensperg was at one time a rival of Hull, and a port so very considerable in 1332, that Edward Baliol and the confederate English barons sailed from hence to invade Scotland; and Henry IV., in 1399, made choice of this port to land at, to effect the deposal of Richard II.; yet the whole of this has since been devoured by the merciless ocean; extensive sands, dry at low water, are to be seen in their stead." The same writer also describes Spurn Point as shaped like a sickle, and the land to the north, he says, was "perpetually preyed on by the fury of the German Sea, which devours whole acres at a time."

The decay of the shores of Norfolk and Suffolk is also remark-

ably rapid. Sir Charles Lyell relates some facts which throw an interesting light on the ravages which the sea commits upon the land here. It was computed that when a certain inn was built at Sherringham, seventy years would pass before the sea could reach the spot: "the mean loss of land being calculated from previous observations to be somewhat less than one yard annually." But no allowance had been made for the fact that the ground sloped *from* the sea. In consequence of this peculiarity, the waste became greater and greater every year as the cliff grew lower. "Between the years 1824 and 1829, no less than seventeen yards were swept away;" and when Sir Charles Lyell saw the place, only a small garden was left between the building and the sea. I need hardly add that all vestiges of the inn have long since disappeared. Lyell also relates that, in 1829, there was a depth of water sufficient to float a frigate at a point where, less than half a century before, there stood a cliff fifty feet high with houses upon it.

I have selected these portions of the coast of Great Britain, not because the destruction of our shores is greater here than elsewhere, but as serving to illustrate processes of waste and demolition which are going on around all the shores, not merely of Great Britain, but of every country on the face of the earth. Here and there, as I have said, there are instances in which a contrary process seems to be in action. Low-lying banks and shoals are formed—sometimes along stretches of coast extending for a considerable distance. But when we consider these formations closely, we find that they rather afford evidence of the energy of the destructive forces to which the land is subject than promise to make up for the land which has been swept away. In the first place, every part of these banks consists of the débris of other coasts. Now we cannot doubt that of earth which is washed away from our shores, by far the larger part finds its way to the bottom of the deep seas; a small proportion only can be brought (by some peculiarity in the distribution of ocean-currents, or in the progress of the tidal wave) to aid in the formation of shoals and banks. The larger, therefore, such shoals and banks may be, the larger must be the amount

of land which has been washed away never to reappear. And although banks and shoals of this sort grow year by year larger and larger, yet (unless added to artificially) they continue always either beneath the surface of the water in the case of shoals, or but very slightly raised above the surface. Now, if we suppose the destruction of land to proceed unchecked, it is manifest that at some period, however remote, the formation of shoals and banks must come to an end, owing to the continual diminution of the land from the demolition of which they derive their substance. In the meantime, the bed of the sea would be continually filling up, the level of the sea would be continually rising, and thus the banks would be either wholly submerged through the effect of this cause alone, or they would have so slight an elevation above the sea-level that they would offer little resistance to the destructive effects of the sea, which would then have no other land to act upon.

But we have yet to consider the second principal cause of the wasting away of the land. The cause we have just been dealing with acts upon the shores or outlines of islands and continents; the one we have now to consider acts upon their interior. Many, perhaps, would hardly suppose that the fall of rain upon the land could have any appreciable influence in the demolition of continents; but, as a matter of fact, there are few causes to which geologists attribute more importance. The very fact that enormous deltas have been formed at the mouths of many rivers—in other words, the actual growth of continents through the effects of rainfall—is a proof how largely this cause must tend to destroy and disintegrate the interiors of our continents. Dwelling on this spoint, Sir Charles Lyell presents the following remarkable illustration: "During a tour in Spain," he writes, "I was surprised to see a district of gently undulating ground in Catalonia, consisting of red and grey sandstone, and in some parts of red marl, almost entirely denuded of herbage; while the roots of the pines, holm oaks, and some other trees, were half exposed, as if the soil had been washed away by a flood. Such is the state of the forests, for example, between Oristo and Vich, and near San Lorenzo. But being

overtaken by a violent thunderstorm in the month of August, I saw the whole surface, even the highest levels of some flat-topped hills, streaming with mud, while on every declivity the devastation of torrents was terrific. The peculiarities in the physiognomy of the district were at once explained; and I was taught that, in speculating on the greater effects which the direct action of rain may once have produced on the surface of certain parts of England, we need not revert to periods when the heat of the climate was tropical."

Combining the effects of the sea's action upon the shores of continents, and of the action of rain upon their interior, and remembering that unless the process of demolition were checked in some way, each cause would act from year to year with new force—one through the effects of the gradual rise of the sea-bed, and the other through the effects of the gradual increase of the surface of ocean exposed to the vaporising action of the sun, which increase would necessarily increase the quantity of rain yearly precipitated on the land—we see the justice of the opinion expressed by Sir John Herschel, that, "had the primeval world been constructed as it now exists, time enough has elapsed, and force enough directed to that end has been in activity, *to have long ago destroyed every vestige of land*."

We see, then, the necessity that exists for the action of some restorative or preservative force sufficient to counteract the effects of the continuous processes of destruction indicated above. If we consider, we shall see that the destructive forces owe their efficiency to their levelling action, that is, to their influence in reducing the solid part of the earth to the figure of a perfect sphere; therefore the form of force which is required to counteract them is one that shall tend to produce irregularities in the surface-contour of the earth. And it will be remarked, that although *upheaval* is the process which appears at first sight to be the only effectual remedy to the levelling action of rains and ocean-currents, yet the forcible depression of the earth's surface may prove in many instances yet more effective, since it may serve to reduce the sea-level in other places.

Now, the earth's subterranean forces serve to produce the very effects which are required in order to counteract the continual disintegration of the shores and interior parts of continents. In the first place, their action is not distributed with any approach to uniformity over different parts of the earth's crust, and therefore the figure they tend to give to the surface of that crust is not that of a perfect sphere. This, of itself, secures the uprising of some parts of the solid earth above the sea-level. But this is not all. On a comparison of the various effects due to the action of subterranean forces, it has been found that the forces of upheaval act (on the whole) more fully under continents, and especially under the shore-lines of continents, while the forces of depression act most powerfully (on the whole) under the bed of the ocean. It need hardly be said that whenever the earth is upheaved in one part, it must be depressed somewhere else. Not necessarily at the same instant, it should be remarked. The process of upheaval may be either momentarily accompanied by a corresponding process of depression, or the latter process may take place by a gradual action of the elastic powers of the earth's crust; but, in one way or the other, the balance between upheaval and depression must be restored. Hence, if it can be shown that for the most part the forces of upheaval act underneath the land, it follows—though we may not be able to recognise the fact by obvious visible signs—that processes of depression are taking place underneath the ocean. Now, active volcanoes mark the centre of a district of upheaval, and most volcanoes are near the sea, as if (though, of course, this is not the true explanation) Nature had provided against the inroads of the ocean by seating the earth's upheaving forces just where they are most wanted.

Even in earthquake districts which have no active vent, the same law is found to prevail. It is supposed by the most eminent seismologists that earthquake regions around a volcano, and earthquake regions apparently disconnected from any outlet, differ only in this respect, that in the one case the subterranean forces have had sufficient power to produce the

phenomena of eruption, while in the other they have not. "In earthquakes," says Humboldt, "we have evidence of a volcano-producing force; but such a force, as universally diffused as the internal heat of the globe, and proclaiming itself everywhere, rarely acts with sufficient energy to produce actual eruptive phenomena; and when it does so, it is only in isolated and particular places."

Of the influence of the earth's subterranean forces in altering the level of land, I might quote many remarkable instances, but considerations of space compel me to confine myself to two or three. The slow processes of upheaval or depression may, perhaps, seem less immediately referable to subterranean action than those which are produced during the progress of an actual earthquake. I pass over, therefore, such phenomena as the gradual uprising of Sweden, the slow sinking of Greenland, and (still proceeding westward) the gradual uprising of Nova Scotia and the shores of Hudson's Bay. Remarkable and suggestive as these phenomena really are, and indisputable as the evidence is on which they rest, they will probably seem much less striking to the reader than those which I am now about to quote.

On the 19th of November, 1822, a widely felt and destructive earthquake was experienced in Chili. On the next day, it was noticed for the first time that a broad line of sea-coast had been deserted by the sea for more than one hundred miles. A large part of this tract was covered by shell-fish, which soon died, and exhaled the most offensive effluvia. Between the old low-water mark and the new one, the fishermen found burrowing shells, which they had formerly had to search for amidst the surf. Rocks some way out to sea which had formerly been covered, were now dry at half ebb-tide.

Careful measurements showed that the rise of the land was greater at some distance inshore than along the beach. The watercourse of a mill about a mile inland from the sea had gained a fall of fourteen inches in little more than a hundred yards. At Valparaiso, the rise was three feet; at Quintero, four feet.

In February, 1835, and in November, 1837, a large tract of

Chili was similarly shaken, a permanent rise of two feet following the former earthquake, and a rise of eight feet the latter.

The earthquake which took place at Cutch in 1819 is perhaps in some respects yet more remarkable. In this instance, phenomena of subsidence, as well as phenomena of upheaval, were witnessed. The estuary of the Indus, which had long been closed to navigation—being, in fact, only a foot deep at ebb-tide, and never more than six feet at flood—was deepened in parts to more than eighteen feet at low water. The fort and village of Sindree were submerged, only the tops of houses and walls being visible above the water. But although this earthquake seemed thus to have a land-destroying, instead of a land-creating effect, yet the instances of upheaval were, even in this case, far more remarkable than those of depression. "Immediately after the shock," says Sir Charles Lyell, "the inhabitants of Sindree saw at a distance of five miles and a half from their village a long elevated mound, where previously there had been a low and perfectly level plain. To this uplifted tract they gave the name of Ulla-Bund, or the 'Mound of God,' to distinguish it from several artificial dams previously thrown across the eastern arm of the Indus. It has been ascertained," he adds, "that this new-raised country is upwards of fifty miles in length from east to west, running parallel to the line of subsidence which caused the grounds around Sindree to be flooded. The breadth of the elevation is conjectured to be in some parts sixteen miles, and its greatest ascertained height above the original level of the delta is ten feet—an elevation which appears to the eye to be very uniform throughout."

QUESTIONS AND EXERCISES

This selection is an example of a single idea explained carefully and fully after a simple and clear plan, with a good deal of concreteness and vividness.

1. In a single sentence give the point of this article.
2. Analyze and explain the plan of the selection. Why is so much time spent in explaining the two ways in which water acts as a destructive agent?

3. Are the concrete illustrations well selected? Examine especially those at the end of the selection. Are they helpful, or would the close be better without them?

Exercise 1. Explain in the manner of Proctor, one of the following topics:

The usefulness of lightning.
On what theory is vivisection justified?
The value of poetry.
The value of birds to the farmer.
The value of fairy tales.

Exercise 2. Write an essay on the value of the dime novel. The following statement, which appeared in an account of an interview with Eugene T Sawyer, the author of the Nick Carter series of dime novels (see *Bookman*, August, 1902), may be made the basis of the essay:

"To a man whose life is measured by yards of ribbon and pounds of cheese, or bounded by the four dingy walls of the counting house, a dime novel is a revelation and a delight. Most of my readers are mere 'supers' on the stage of life. They are not in themselves picturesque. Nothing romantic ever happens to them. For all these, the dime novel provides a thrill per page, the only real mental stimulus they are capable of. The heroes that strut through the pages of 'yellowback' are the only interesting persons they ever hob-nob with. No wonder they all love Nick Carter."

ON THE SCIENCE OF EASY CHAIRS[1]

Sir T. Lauder Brunton

There is a reason for everything if we can only find it out, but it is sometimes very hard to discover the reasons of even the very simplest things. Every one who has travelled much, and even those who have merely looked through books of travels, must have been struck by the variety of attitudes assumed by the people of different countries. The Hindoo sits down on the

[1] Reprinted from *Collected Papers on Circulation and Respiration, First Series*, by permission of the publishers, The Macmillan Company.

ground with his knees drawn up close to his body, so that his chin will almost rest upon them; the Turk squats down cross-legged; the European sits on a chair; while the American often raises his legs to a level with his head. Nor are the postures assumed by the same people under varying circumstances less diverse. Climate or season, for example, will cause considerable alteration in the posture assumed, as was well shown by Alma Tadema, in his pictures of the four seasons exhibited in the Academy a year ago. In his representation of Summer he painted a woman leaning backwards on a ledge, with one leg loosely hanging down, while the other was drawn up so that the foot was on a level with the body. In the picture of Winter, on the other hand, we saw a figure with the legs drawn up in front of the belly. The reason for these different postures has been explained by Rosenthal. The temperature of the body, as is well known, is kept up and regulated by the circulation of the blood through it, and a great proportion of the blood contained in the whole body circulates in the vessels of the intestines. Now, the intestines are only separated from the external air by the thin abdominal walls, and therefore any change of temperature in the atmosphere will readily act upon them unless they be guarded by some additional protection. The Hindoos are well aware of this, and they habitually protect the belly by means of a thick shawl or camarband, thus guarding themselves against any sudden change of temperature. This precaution is also frequently adopted by Europeans resident in hot climates, and is even retained by them after returning to England. But the function of the camarband may, to a certain extent, be fulfilled by change of posture alone. When the legs are drawn up, as in the picture of Winter already referred to, the thighs partially cover the abdomen, and taking the place of additional clothing, aid the abdominal walls in protecting the intestines and the blood they contain from the cooling influence of the external air.

Thus it is that in cold weather, when the quantity of covering in bed is insufficient, persons naturally draw up their legs towards the abdomen, so as to retain as much heat as possible

before going to sleep. In hot weather, on the contrary, they wish to expose the abdomen as much as possible to the cooling influence of the atmosphere. The posture depicted by Alma Tadema is the most efficient for this purpose. It no doubt answers the purpose to lie down flat on one's back, but in this position the abdominal walls are more or less tight, whereas, when one of the legs is drawn up as in the painting just alluded to, the walls are relaxed, and the intestines not being subject to any pressure, the blood in them will circulate more rapidly, and cooling process be carried on more effectually. In this attitude also the thighs are completely separated, and loss of heat allowed from their whole surface.

Varying conditions of fatigue also alter the postures which people assume. When slightly tired one is content to sit down in an ordinary chair in the position of the letter **N** with the middle limb horizontal. As we get more and more fatigued we usually assume positions in which the limbs of the **N** become more and more oblique, the trunk leaning backwards and the legs extending forwards. If we lie down in bed on our back the legs will probably become straight, but if we rest upon our side they will become more or less bent. The straightness of the legs in the supine position is simply due to their weight, which is then supported at every point by the bed, but when we lie on our sides the genuflexion of the legs is most agreeable, because not only are the muscles more perfectly relaxed, but, as the late Professor Goodsir pointed out, the bones which form the knee-joint are slightly removed from one another, and thus the joint itself, as well as the muscles, passes into a state of rest. Some of the bamboo easy chairs manufactured in India allow us to obtain the advantages of both positions. These chairs are made in the form of a somewhat irregular straggling **W**, and in them one can lie on one's back with every part of the body thoroughly supported, and the knees bent in the same way as they would be if one lay upon one's side.

Thus simple inaction, the relaxation of the muscles, and the laxity of joints are some of the factors necessary for complete rest, and an easy chair, to be perfect, must secure them all.

But it is possible for an easy chair to secure all of these and yet be imperfect. We have just said that usually, as the fatigue becomes greater and greater, the tendency is to assume the position of the **N** with the limbs at a more or less obtuse angle, but when sitting in an ordinary chair we find relief from raising the feet by means of a foot-stool, although this tends to make the angles of the **N** more acute instead of more obtuse. Still more relief, however, do we obtain when the legs are raised up on a level with the body by being placed upon another chair, or by being rested on the Indian bamboo seat already described. If, in addition to this, the legs are gently shampooed upwards, the sensation is perfectly delightful, and the feelings of fatigue are greatly lessened. To understand how this can be, it is necessary for us to have some idea as to the cause of fatigue. Any muscular exertion can be performed for a considerable time by a man in average health without the least feeling of fatigue, but by and by the muscles become weary, and do not respond to the will of their owner so rapidly as before; and if the exertion be too great, or be continued for too long a time, they will ultimately entirely refuse to perform their functions. The muscle, like a steam engine, derives the energy which it expends in mechanical work from the combustion going on within it, and this combustion, in both cases, would come to a standstill if waste products or ashes were not removed. It is these waste products of the muscle which, accumulating within it, cause fatigue, and ultimately paralyze it. This has been very neatly shown by Kronocker, who caused a frog's muscle, separated from the body, to contract until it entirely ceased to respond to a stimulus. He then washed out the waste products from it by means of a little salt and water, and found that its contractile power again returned, just as the power of the steam engine would be increased by raking the ashes which were blocking up the furnace and putting out the fire. These waste products are partly removed from the muscles by the blood which flows through them, and are carried by the veins into the general circulation. There they undergo more complete combustion, and tend to keep up the temperature of the body. At the same

time, however, according to Preyer, they lessen the activity of the nervous system, producing a tendency to sleep, and in this way he would, at least to some extent, explain the agreeable drowsiness which comes on after muscular exertion. It would seem, however, that the circulation of the blood is insufficient to remove all the waste products from the muscles, for we find that they are supplied with a special apparatus for this purpose. Each muscle is generally ensheathed in a thin membrane, or fascia, and besides these we have thicker fasciæ ensheathing whole limbs. These fasciæ act as a pumping apparatus, by which the products of waste may be removed from the muscles they invest. They consist of two layers, with spaces between. When the muscle is at rest these layers separate, and the spaces become filled with fluid derived from the muscle, and when the muscle contracts it presses the two layers of the investing sheath together and drives out the fluid contained between them. This passes onwards into the lymphatics, where a series of valves prevent its return, and allow it only to move onwards, till at last it is emptied into the general circulation.

In strong and healthy people the veins and lymphatics together are quite able to take up all the fluid which the arteries have supplied to the muscles, and thus prevent any accumulation from taking place in them or in the cellular tissue adjoining them, or at least prevent any such accumulation as might become evident to the eye. In delicate, weakly persons, or in those who suffer from certain diseases of the vascular system, this is not the case; and after standing or walking for a long time the legs become swollen, so that the boots feel tight, and sometimes even a distinct impression may be remarked at that part of the ankle which was uncovered by the boot. In such persons we can actually see the swelling disappear after the feet have been kept rested for some time on a level with the body, and it may be removed more quickly still by gently and steadily rubbing the limbs in one direction from below upwards. It is almost certain that what we thus see in weakly persons occurs to a slighter extent in all, and that even in the most healthy persons after a long walk a slight accumulation of fluid,

laden with the products of muscular waste, occurs both in the muscles themselves, and in the cellular tissue around them, even although we cannot detect it by simple inspection. So long as the limbs of such a person hang down, the force of gravity retards the return both of blood through the veins and of lymph through the fasciæ and lymphatics, and thus hinders the muscles from getting rid of those waste products which cause the fatigue. When the legs are raised, this hindrance is at once removed, both blood and lymph return more readily from the muscles, carrying with them those substances which had been formed by the muscles of the limbs during the exertions which they had undergone when carrying the body about. So long as these substances remained where they had been formed, they might cause in the muscles an undue amount of fatigue, although when distributed over the body generally, they may produce only a pleasing languor. When the legs are long, the obstruction to the return of blood and lymph is of course greater than when they are short, and this return will take place more readily when the legs are raised above the body than when they are only on a level with it. This may be one of the reasons why some of our long-legged American cousins are so fond of raising their feet to a level with their heads, or even higher, although it is very probable that there are reasons still more powerful, which we may discuss at a future time.

It has already been mentioned that the lymph is propelled along the interstices of the fasciæ into the lymphatic vessels by the intermittent pressure which the muscle exerts upon them from within, and it seems natural to suppose that the flow may also be aided by a pressure from without, in the form of shampooing. Even when the hand is rubbed backwards and forwards upon the leg it will relieve fatigue, but the relief is greater when the leg is firmly grasped and the hand moved gently upwards so as to drive onwards as much as possible any fluid which may have accumulated in the limb, and the grasp being then relaxed, the same process should be repeated.

But while the lymph is thus most readily removed by the pumping action of intermittent pressure either of the hand

without or of the muscles alternately contracting and relaxing within, it seems to us probable that this process may also be aided by steady, constant pressure from without. No doubt it is impossible for such a steady pressure to take the place of the regular pumping action produced by the alternate contraction and relaxation of the muscles when in action, yet it will have a somewhat similar action, though to a very much less extent. For at each beat of the heart, as Mosso shows, the entire limb is distended by the blood driven into the vessels, and during the pauses between the beats it again becomes smaller. Each pulse, therefore, by distending the whole limb and each individual muscle, will press out a little of the fluid contained in the fasciæ in the same way as the contractions of the muscles themselves, and it seems to us probable that it is the aid which is afforded to this process by the gentle pressure exerted on the outside of the legs by a seat which supports them along their whole extent, that renders such a seat so peculiarly restful and agreeable. For an easy chair to be perfect, therefore, it ought not only to provide for complete relaxation of the muscles, for flexion and consequent laxity of the joints, but also for the easy return of blood and lymph not merely by the posture of the limbs themselves, but by equable support and pressure against as great a surface of the limbs as possible. Such are the theoretical demands, and it is interesting to notice how they are all fulfilled by the aforementioned chair in the shape of a straggling **W**, which the languor consequent upon a relaxing climate has taught the natives of India to make, and which is known all over the world.

QUESTIONS AND EXERCISES

Although somewhat faulty in the details of composition, especially sentence-construction, this selection as a whole is a good example of the clear and interesting presentation of the scientific principles underlying a very commonplace fact.

1. State in your own words the main thought of the selection. What divisions and subdivisions do you discover in the piece? Make an outline.

2. Is the explanation clear at every point to you? If the selection

is found faulty in this respect, consider the possible class of readers for whom it was originally intended and determine whether it has been made clear enough for them.

3. Does the subject seem at first so commonplace as to offer little opportunity for the display of scientific knowledge? Because of its familiarity is there the greater need for skill in explaining so as to arouse interest? In your opinion has the writer made his explanation interesting? By what devices?

4. Do the paragraphs show a tendency to be too long? Would shorter ones make the reading of the piece easier? Make suggestions for a re-division into shorter paragraphs. Point out instances of carelessness in sentence construction. How far is the language of this selection technical? Has the writer generally used familiar words?

Exercise 1. Select from the list below a subject, and write a short explanation of the principle or law connected with it. Assume that your reader is familiar with the object itself and do not spend much time on a description of it. Bring out clearly the scientific principle illustrated by it.

Artesian wells.
The fountain pen.
The rotary lawn sprinkler.
The Welsbach burner.
The vacuum cleaner.
The Bunsen burner.
The incandescent lamp.
The Thermos bottle.
The Maxim silencer for rifles.
The megaphone.
The compass.
The Cartesian diver.
The opera glass.
The fireless cooker.
The prism binocular.
Ventilation of buildings.
The science of treading water, or swimming on the back.
Why one leans forward in climbing a hill.
The coolness of white clothing on a hot day.
What to do and what not to do in making a camp-fire—with reasons.

Drying clothes by putting them into a large cylinder with holes in the sides, and setting it in rapid rotation.

Exercise 2. Write a short discussion of the science of exercise, showing what you think to be the ideal form of sport for this purpose.

ON YEAST[1]

Thomas Henry Huxley

I have selected to-night the particular subject of Yeast for two reasons—or, rather, I should say for three. In the first place, because it is one of the simplest and the most familiar objects with which we are acquainted. In the second place, because the facts and phenomena which I have to describe are so simple that it is possible to put them before you without the help of any of those pictures or diagrams which are needed when matters are more complicated, and which, if I had to refer to them here, would involve the necessity of my turning away from you now and then, and thereby increasing very largely my difficulty (already sufficiently great) in making myself heard. And thirdly, I have chosen this subject because I know of no familiar subject forming part of our everyday knowledge and experience, the examination of which, with a little care, tends to open up such very considerable issues as does this substance —yeast.

In the first place, I should like to call your attention to a fact with which the whole of you are, to begin with, perfectly acquainted; I mean the fact that any liquid containing sugar, any liquid which is formed by pressing out the succulent parts of the fruits of plants, or a mixture of honey and water, if left to itself for a short time, begins to undergo a peculiar change. No matter how clear it might be at starting, yet after a few hours, or at most a few days, if the temperature is high, this liquid

[1] A lecture delivered in the Free Trade Hall, Manchester, England, Nov. 3, 1871. Reprinted from *Half-Hour Recreations in Popular Science, No. 8* (Dana Estes Co.).

begins to be turbid, and by and by bubbles make their appearance in it, and a sort of dirty-looking yellowish foam or scum collects at the surface; while at the same time, by degrees, a similar kind of matter, which we call the "lees," sinks to the bottom.

The quantity of this dirty-looking stuff that we call the scum and lees goes on increasing until it reaches a certain amount and then it stops; and by the time it stops, you find the liquid in which this matter has been formed has become altered in its quality. To begin with, it was a mere sweetish substance, having the flavor of whatever might be the plant from which it was expressed, or having merely the taste and absence of smell of a solution of sugar; but by the time this change that I have been briefly describing to you is accomplished, the liquid has become completely altered; it has acquired a peculiar smell, and, what is still more remarkable, it has gained the property of intoxicating the person who drinks it. Nothing can be more innocent than a solution of sugar; nothing can be less innocent if taken in excess, as you all know, than those fermented matters which are produced from sugar. Well, again, if you notice that bubbling, or, as it were, seething of the liquid which has accompanied the whole of this process, you will find that it is produced by the evolution of little bubbles of air-like substances out of the liquid; and I dare say you all know this air-like substance is not like common air; it is not a substance which a man can breathe with impunity. You often hear of accidents which take place in brewers' vats when men go in carelessly, and get suffocated there without knowing that there was anything evil awaiting them. And if you tried the experiment with this liquid I am telling of while it was fermenting, you would find that any small animal let down into the vessel would be similarly stifled; and you would discover that a light lowered down into it would go out. Well, then, lastly, if after this liquid has been thus altered you expose it to that process which is called distillation,—that is to say, if you put it into a still, and collect the matters which are sent over,—you obtain, when you first heat it, a clear, transparent liquid, which, however,

is something totally different from water: it is much lighter; it has a strong smell, and it has an acrid taste; and it possesses the same intoxicating power as the original liquid, but in a much more intense degree. If you put a light to it, it burns with a bright flame, and it is that substance which we know as spirits of wine.

Now, these facts which I have just put before you—all but the last—have been known from extremely remote antiquity. It is, I hope, one of the best evidences of the antiquity of the human race that among the earliest records of all kinds of men you find a time recorded when they got drunk. We may hope that that must have been a very late period in their history. Not only have we the record of what happened to Noah, but if we turn to the traditions of different people, those forefathers of ours who lived in the high lands of northern India, we find that they were not less addicted to intoxicating liquids; and I have no doubt that the knowledge of this process extends far beyond the limits of historically recorded time. And it is a very curious thing to observe that all the names we have of this process, and all that belongs to it, are names that have their roots not in our present language, but in those older languages which go back to the times at which this country was peopled. That word "fermentation," for example, which is the title we apply to the whole process, is a Latin term; and a term which is evidently based upon the fact of the effervescence of the liquid. Then the French, who are very fond of calling themselves the Latin race, have a particular word for ferment, which is *levure*. And in the same way we have the word "leaven," those two words having reference to the heaving up, or to the raising of the substance which is fermented. Now, those are words which we get from what I may call the Latin side of our parentage; but if we turn to the Saxon side, there are a number of names connected with this process of fermentation. For example, the Germans call fermentation—and the old Germans did so—*gähren;* and they call anything which is used as a ferment by such names, such as *gheist* and *geest*, and finally in low German, *ghest;* and that word, you know, is the word

our Saxon forefathers used, and is almost the same as the word which is commonly employed in this country to denote the common ferment of which I have been speaking. So they have another name, the word *hefe*, which is derived from their verb *heben*, which signifies to raise up; and they have yet a third name, which is also one common in this country (I do now know whether it is common in Lancashire, but it is certainly very common in the Midland counties), the word *barm*, which is derived from a root which signifies to raise or to bear up. Barm is a something borne up; and thus there is much more real relation than is commonly supposed by those who make puns, between the beer which a man takes down his throat and the bier upon which that process if carried to excess generally lands him, for they are both derived from the root signifying bearing up; the one thing is borne upon men's shoulders, and the other is the fermented liquid which was borne up by the fermentation taking place in itself.

Again, I spoke of the produce of fermentation as "spirits of wine." Now, what a very curious phrase that is, if you come to think of it. The old alchemists talked of the finest essence of anything as if it had the same sort of relation to the thing itself as a man's spirit is supposed to have to his body; and so they spoke of this fine essence of the fermented liquid as being the spirit of the liquid. Thus came about that extraordinary ambiguity of language, in virtue of which you apply precisely the same substantive name to the soul of man and a glass of gin! And then there is still one other most curious piece of nomenclature connected with this matter, and that is the word "alcohol" itself, which is now so familiar to everybody. Alcohol originally meant a very fine powder. The women of the Arabs and other Eastern peoples are in the habit of tinging their eyebrows with a very fine black powder which is made of antimony, and they call that "kohol;" and the "al" is simply the article put in front of it, so as to say "the kohol." And up to the seventeenth century in this country the word alkohol was employed to signify any very fine powder: you find in Robert Boyle's works that he uses "alcohol" for a very fine,

subtile powder. But, then, this name of anything very fine and very subtile came to be specially connected with this fine and subtile spirit obtained from the fermentation of sugar; and I believe that the first person who fairly fixed it as a proper name of what we now commonly call spirits of wine, was the great French chemist, Lavoisier, so comparatively recent is the word alcohol in this specialized sense.

So much by way of general introduction to the subject on which I have to speak to-night. What I have hitherto stated is simply what we may call common knowledge, which everybody may acquaint himself with. And you know that what we call scientific knowledge is not any kind of conjuration, as people sometimes suppose, but it is simply the application of the same principles of common sense that we apply to common knowledge, carried out, if I may so speak, to knowledge which is uncommon. And all that we know now of this substance, yeast, and all the very strange issues to which that knowledge has led us, has simply come out of the inveterate habit—and a very fortunate habit for the human race it is—which scientific men have of not being content until they have routed out all the different chains and connections of apparently simple phenomena, until they have taken them to pieces and understood the conditions upon which they depend. I will try to point out to you now what has happened in consequence of endeavoring to apply this process of "analysis," as we call it, this teasing out of an apparently simple fact into all the little facts of which it is made up, to the ascertained facts relating to the barm or the yeast; secondly, what has come of the attempt to ascertain distinctly what is the nature of the products which are produced by fermentation; then what has come of the attempt to understand the relation between the yeast and the products; and lastly, what very curious side issues—if I may so call them—have branched out in the run of this inquiry, which has now occupied somewhere about two centuries.

The first thing was to make out precisely and clearly what was the nature of this subject, this apparently mere scum and mud that we call yeast. And that was first commenced seriously

by a wonderful old Dutchman of the name of Leeuwenhoek, who lived some two hundred years ago, and who was the first person to invent thoroughly trustworthy microscopes of high powers. Now, Leeuwenhoek went to work upon this yeast mud, and by applying to it high powers of the microscope, he discovered that it was no mere mud such as you might at first suppose, but that it was a substance made up of an enormous multitude of minute grains, each of which had just as definite a form as if it were a grain of corn, although it was infinitely smaller, the largest of these not being more than the two-thousandth of an inch in diameter; while, as you know, a grain of corn is a large thing; and the very smallest of these particles were not more than the seven-thousandth of an inch in diameter. Leeuwenhoek saw that this muddy stuff was in reality a liquid, in which there were floating this immense number of definitely shaped particles, all aggregated in heaps and lumps, and some of them separate. That discovery remained, so to speak, dormant for fully a century, and then the question was taken up by a French discoverer, who, paying great attention and having the advantage of better instruments than Leeuwenhoek, had watched these things, and made the astounding discovery that they were bodies which were constantly being reproduced and growing; that when one of these rounded bodies was once formed and had grown to its full size, it immediately began to give off a little bud from one side, and then that bud grew out until it had attained the full size of the first, and that in this way the yeast particle was undergoing a process of multiplication by budding, just as effectual and just as complete as the process of multiplication of a plant by budding; and thus this Frenchman, Cagniard de la Tour, arrived at the conclusion—very creditable to his sagacity, and which has been confirmed by every observation and reasoning since—that this apparent muddy refuse was neither more nor less than a mass of plants, of minute living plants, growing and multiplying in the sugary fluid in which the yeast is formed. And from that time forth we have known this substance which forms a scum and the lees as the yeast plant, and it has received

a scientific name—which I may use without thinking of it, and which I will therefore give you—namely, "Torula." Well, this was a capital discovery. The next thing to do was to make out how this torula was related to other plants. I won't worry you with the whole course of investigation, but I may sum up its results, and they are these—that the torula is a particular kind of a fungus, a particular state, rather, of a fungus or mould. There are many moulds which, under certain conditions, give rise to this torula state, to a substance which is not distinguishable from yeast, and which has the same properties as yeast—that is to say, which is able to decompose sugar in the curious way that we shall consider by and by. So that the yeast plant is a plant belonging to a group of the Fungi, multiplying, and growing, and living, in this very remarkable manner, in the sugary fluid, which is, so to speak, the nidus or home of the yeast.

That, in a few words, is as far as investigation—by the help of one's eye and by help of the microscope—has taken us. But now there is an observer whose methods of observation are more refined than those of men who use their eye, even though it be aided by the microscope; a man who sees indirectly farther than we can see directly—that is, the chemist; and the chemist took up this question, and his discovery was not less remarkable than that of the microscopist. The chemist discovered that the yeast plant being composed of a sort of bag, like a bladder, inside which is a peculiar soft, semifluid material,—the chemist found that this outer bladder has the same composition as the substance of wood, that material which is called "cellulous," and which consists of the elements carbon, and hydrogen, and oxygen, without any nitrogen. But then he also found (the first person to discover it was an Italian chemist, named Fabroni, in the end of the last century) that this inner matter which was contained in the bag, which constituted the yeast plant, was a substance containing the elements carbon, and hydrogen, and oxygen, and nitrogen; that it was what Fabroni called vegeto-animal substance, and that it had the peculiarity of what are commonly called "animal products."

This, again, was an exceedingly remarkable discovery. It lay neglected for a time, until it was subsequently taken up by the great chemists of modern times, and they, with their delicate methods of analysis, have finally decided that, in all essential respects, that substance which forms the chief part of the contents of the yeast plant is identical with the material which forms the chief part of our own muscles, which forms the chief part of our own blood, which forms the chief part of the white of the egg; that, in fact, although this little organism is a plant, and nothing but a plant, yet that its active living parts contain a substance which is called "protein," which is of the same nature as the substance which forms the foundation of every animal organism whatever.

Now we come next to the question of the analysis of the products, of that which is produced during the process of fermentation. So far back as the beginning of the sixteenth century, in the times of transition between the old alchemy and the modern chemistry, there was a remarkable man, Van Helmont, a Dutchman, who saw the difference between the air which comes out of a vat where something is fermented and common air. He was the man who invented the term "gas," and he called this kind of gas *gas silvestre*,—so to speak, gas that is wild and lives in out of the way places,—having in his mind the identity of this particular kind of air with that which is found in some caves and cellars. Then, the gradual process of investigation going on, it was discovered that this substance, then called "fixed air," was a poisonous gas, and it was finally identified with that kind of gas which is obtained by burning charcoal in the air, which is called "carbonic acid." Then the substance alcohol was subjected to examination, and it was found to be a combination of carbon, and hydrogen, and oxygen. Then the sugar which was contained in the fermenting liquid was examined, and was found to contain the three elements, carbon, hydrogen, and oxygen. So that it was clear there were in sugar the fundamental elements which are contained in carbonic acid and in alcohol. And then came that great chemist, Lavoisier, and he examined into the subject carefully, and

possessed with that brilliant thought of his, which happened to be propounded exactly apropos to this matter of fermentation—that no matter is ever lost, but that matter only changes its form and changes its combinations—he endeavored to make out what became of the sugar which was subjected to fermentation. He thought he discovered that the whole weight of the sugar was represented by the weight of the alcohol produced, added to the weight of the carbonic acid produced; that, in other words, supposing this tumbler to represent the sugar, the action of fermentation was as it were the splitting of it, the one half going away in the shape of carbonic acid, and the other half going away in the shape of alcohol. Subsequent inquiry, careful research with the refinements of modern chemistry, have been applied to this problem, and they have shown that Lavoisier was not quite correct; that what he says is quite true for about 95 per cent. of the sugar, but that the other 5 per cent. or nearly so is converted into two other things; one of them matter which is called succinic acid, and the other matter which is called glycerine, which you all know now as one of the commonest of household matters. It may be that we have not got to the end of this refined analysis yet, but at any rate, I suppose I may say,—and I speak with some little hesitation for fear my friend Professor Roscoe here may pick me up for trespassing upon his province,—but I believe I may say that now we may account for ninety-nine per cent. at least of the sugar, and that ninety-nine per cent. is split up into these four things: carbonic acid, alcohol, succinic acid, and glycerine. So that it may be that none of the sugar whatever disappears, and that only its parts, so to speak, are rearranged, and if any of it disappears, certainly it is a very small portion.

Now, these are the facts of the case. There is the fact of the growth of the yeast plant; and there is the fact of the splitting up of the sugar. What relation have these two facts to one another?

For a very long time that was a great matter of dispute. The early French observers, to do them justice, discerned the real state of the case, namely, that there was a very close con-

nection between the actual life of the yeast plant and this operation of the splitting up of the sugar; and that one was in some way or other connected with the other. All investigation subsequently has confirmed this original idea. It has been shown that if you take any measures by which other plants of like kind to the torula would be killed, and by which the yeast plant is killed, then the yeast loses its efficiency. But a capital experiment upon this subject was made by a very distinguished man, Helmholtz, who performed an experiment of this kind. He had two vessels,—one of them we will suppose full of yeast, but over the bottom of it, as this might be, was tied a thin film of bladder; consequently, through that film of bladder all the liquid parts of the yeast would go, but the solid parts would be stopped behind; the torula would be stopped, the liquid parts of the yeast would go. And then he took another vessel containing a fermentable solution of sugar, and he put one inside the other; and in this way, you see, the fluid parts of the yeast were able to pass through with the utmost ease into the sugar, but the solid parts could not get through at all. And he judged thus: if the solid parts are those which excite fermentation, then, inasmuch as these are stopped, the sugar will not ferment, showing quite clearly that an immediate contact with the solid, living torula was absolutely necessary to excite this process of splitting up the sugar. This experiment was quite conclusive as to this particular point, and has had very great fruits in other directions.

Well, then, the yeast plant being essential to the production of fermentation, where does the yeast plant come from? Here, again, was another great problem opened up, for, as I said at starting, you have under ordinary circumstances, in warm weather, merely to expose some fluid containing a solution of sugar, or some form of syrup or vegetable juice, to the air, in order, after a comparatively short time, to see all these phenomena of fermentation. Of course the first obvious suggestion is, that the torula has been generated in the fluid. In fact it seems at first quite absurd to entertain any other conviction; but that belief would most assuredly be an erroneous one.

Towards the beginning of this century, in the vigorous times of the old French wars, there was a Monsieur Appert, who had his attention directed to the preservation of things that ordinarily perished, such as meats and vegetables; and, in fact, he laid the foundation of our modern method of preserving meats; and he found that if he boiled any of these substances and then tied them so as to exclude the air, they would be preserved for any time. He tried these experiments, particularly with the must of wine and with the wort of beer; and he found that if the wort of beer had been carefully boiled, and was stopped in such a way that the air could not get at it, it would never ferment. What was the reason of this? That, again, became the subject of a long string of experiments, with this ultimate result, that if you take precautions to prevent any solid matters from getting into the must of wine or the wort of beer, under these circumstances,—that is to say, if the fluid has been boiled and placed in a bottle, and if you stuff the neck of the bottle full of cotton wool, which allows the air to go through, and stops anything of a solid character, however fine,—then you may let it be for ten years and it will not ferment. But if you take that plug out, and give the air free access, then, sooner or later, fermentation will set up. And there is no doubt whatever that fermentation is excited only by the presence of some torula or other, and that that torula proceeds, in our present experience, from pre-existing torulæ. These little bodies are excessively light. You car easily imagine what must be the weight of little particles, but slightly heavier than water, and not more than the two-thousandth or perhaps seven-thousandth of an inch in diameter. They are capable of floating about and dancing like motes in the sunbeam; they are carried about by all sorts of currents of air; the great majority of them perish; but one or two, which may chance to enter into a sugary solution, immediately enter into active life, find there the conditions of their nourishment, increase and multiply, and may give rise to any quantity whatever of this substance yeast. And whatever may be true or not be true about this "spontaneous generation," as it is called, in regard to all other kinds of living things,

it is perfectly certain, as regards yeast, that that always owes its origin to this process of impregnation or inoculation, if you like so to call it, from some other living yeast organism; and so far as yeast is concerned, the doctrine of spontaneous generation is absolutely out of court. And not only that, but the yeast must be alive in order to exert these peculiar properties. If it be crushed, if it be heated so far that its life is destroyed, that peculiar power of fermentation is not excited. Thus we have come to this conclusion, as the result of our inquiry, that the fermentation of sugar, the splitting of sugar into alcohol and carbonic acid, glycerine, and succinic acid, is the result of nothing but the vital activity of this little fungus, the torula.

And now comes the further exceedingly difficult inquiry—How is it that this plant, the torula, produces this singular operation of the splitting up of the sugar? Fabroni, to whom I referred some time ago, imagined that the effervescence of fermentation was produced in just the same way as the effervescence of a seidlitz powder; that the yeast was a kind of acid, and that the sugar was a combination of carbonic acid and some base to form the alcohol, and that the yeast combined with this substance, and set free the carbonic acid; just as when you add carbonate of soda to acid you turn out the carbonic acid. But of course the discovery of Lavoisier that the carbonic acid and the alcohol taken together are very nearly equal in weight to the sugar, completely upset this hypothesis. Another view was therefore taken by the French chemist, Thénard, and it is still held by a very eminent chemist, M. Pasteur; and their view is this, that the yeast, so to speak, eats a little of the sugar, turns a little of it to its own purposes, and by so doing gives such a shape to the sugar that the rest of it breaks up into carbonic acid and alcohol.

Well, then, there is a third hypothesis, which is maintained by another distinguished chemist, Liebig, which denies both the other two, and which declares that the particles of the sugar are, as it were, shaken asunder by the forces at work in the yeast plant. Now, I am not going to take you into these refinements of chemical theory; I cannot for a moment pretend to do so;

but I may put the case before you by an apology. Suppose you compare the sugar to a card house, and suppose you compare the yeast to a child coming near the card house; then Fabroni's hypothesis was that the child took half the cards away; Thénard's and Pasteur's hypothesis is, that the child pulls out the bottom card and thus makes it tumble to pieces; and Liebig's hypothesis is, that the child comes by and shakes the table, and tumbles the house down. I appeal to my friend here (Professor Roscoe) whether that is not a fair statement of the case.

Having thus, so far as I can, discussed the general state of the question, it remains only that I should speak of some of those collateral results which have come in a very remarkable way out of the investigation of yeast. I told you that it was very early observed that the yeast plant consisted of a bag made up of the same material as that which composes wood; and of an interior semifluid mass which contains a substance identical in its composition, in a broad sense, with that which constitutes the flesh of animals. Subsequently, after the structure of the yeast plant had been carefully observed, it was discovered that all plants, high and low, are made up of separate bags, or "cells," as they are called; these bags or cells having the composition of the pure matter of wood; having the same composition, broadly speaking, as the sac of the yeast plant, and having in their interior a more or less fluid substance containing a matter of the same nature as the protein substance of the yeast plant. And therefore this remarkable result came out, that however much a plant may differ from an animal, yet that the essential constituents of the contents of these various *cells* or *sacs* of which the plant is made up, the nitrogenous protein matter is the same in the animal as in the plant. And not only was this gradually discovered, but it was found that these semifluid contents of the plant cell had, in many cases, a remarkable power of contractility, quite like that of the substance of animals. And about twenty-four or twenty-five years ago, namely about the year 1846, to the best of my recollection, a very eminent German botanist, Hugo von Mohl, conferred

upon this substance which is found in the interior of the plant cell, and which is identical with the matter found in the inside of the yeast cell, and which again contains an animal substance similar to that of which we ourselves are made up,—he conferred upon this that title of "protoplasm," which has brought other people a great deal of trouble since! I beg particularly to say that, because I find many people suppose that I was the inventor of that term, whereas it has been in existence for at least twenty-five years. And then other observers, taking the question up, came to this astonishing conclusion (working from this basis of the yeast), that the differences between animals and plant are not so much in the fundamental substances which compose them, not in the protoplasm, but in the manner in which the cells of which their bodies are built up have been modified. There is a sense in which it is true—and the analogy was pointed out very many years ago by some French botanists and chemists,—there is a sense in which it is true that every plant is essentially an enormous aggregation of bodies similar to yeast cells, each having, to a certain extent, its own independent life. And there is a sense in which is it also perfectly true—although it would be impossible for me to give the statement to you with proper qualifications and limitations on an occasion like this—but there is also a sense in which it is true that every animal body is made up of an aggregation of minute particles of protoplasm, comparable each of them to the individual separate yeast plant. And those who are acquainted with the history of the wonderful revolution which has been worked in our whole conception of these matters in the last thirty years, will bear me out in saying that the first germ of them, to a very great extent, was made to grow and fructify by the study of the yeast plant, which presents us with living matter in almost its simplest condition.

Then there is yet one last and most important bearing of this yeast question. There is one direction probably in which the effects of the careful study of fermentation will yield results more practically valuable to mankind than any other. Let me recall to your minds the fact which I stated at the beginning

of this lecture. Suppose that I had here a solution of pure sugar with a little mineral matter in it; and suppose it were possible for me to take upon the point of a needle one single, solitary yeast cell, measuring no more probably than the three-thousandth of an inch in diameter—not bigger than one of those little colored specks of matter in my own blood at this moment, the weight of which it would be difficult to express in the fraction of a grain—and put it into this solution. From that single one, if the solution were kept at a fair temperature, in a warm summer's day, there would be generated in the course of a week enough torula to form a scum at the top and to form lees at the bottom, and to change the perfectly tasteless and entirely harmless fluid, syrup, into a solution impregnated with the poisonous gas, carbonic acid, impregnated with the poisonous substance, alcohol; and that in virtue of the changes worked upon the sugar by the vital activity of these infinitesimally small plants. Now you see that this is a case of infection. And from the time that the phenomena of fermentation was first carefully studied, it has constantly been suggested to the minds of thoughtful physicians that there was a something astoundingly similar between the phenomena of the propagation of fermentation by infection and contagion and the phenomena of the propagation of disease by infection and contagion. Out of this suggestion has grown that remarkable theory of many diseases which has been called the "germ theory of disease;" the idea, in fact, that we owe a great many diseases to particles having a certain life of their own, and which are capable of being transmitted from one living being to another, exactly as the yeast plant is capable of being transmitted from one tumbler of saccharine substance to another. And that is a perfectly tenable hypothesis, one which in the present state of medicine ought to be absolutely exhausted and shown not to be true, before we take to others which have less analogy in their favor. And there are some diseases, most assuredly, in which it turns out to be correct. There are some forms of what are called malignant carbuncle which have been shown to be actually effected by a sort of fermentation, if I may use the phrase, by a sort of dis-

turbance and destruction of the fluids of the animal body, set up by minute organisms which are the cause of this destruction and of this disturbance; and only recently the study of the phenomena which accompany vaccination has thrown an immense light in this direction, tending to show by experiment the same general character as that to which I have referred as performed by Helmholtz, that there is a most astonishing analogy between the contagion of that healing disease and the contagion of destructive diseases. For it has been made out quite clearly, by investigation carried on in France and in this country, that the only part of the vaccine matter which is contagious, which is capable of carrying on its influence in the organism of the child who is vaccinated, is the solid particles, and not the fluid. By experiments of the most ingenious kind, the solid parts have been separated from the fluid parts, and it has then been discovered that you may then vaccinate a child as much as you like with the fluid parts, but no effect takes place, though an excessively small portion of the solid particles, the most minute that can be separated, is amply sufficient to give rise to all the phenomena of the cow pock, by a process which we can compare to nothing but the transmission of fermentation from one vessel into another, by the transport to the one of the torula particles which exist in the other. And it has been shown to be true of some of the most destructive diseases which infect animals, such diseases as the sheep pox, such diseases as that most terrible and destructive disorder of horses, glanders, that in these, also, the active power is the living solid particle, and that the inert part is the fluid. However, do not suppose that I am pushing this analogy too far. I do not mean to say that the active, solid parts in these diseased matters are of the same nature as living yeast plants; but, so far as it goes, there is a most surprising analogy between the two; and the value of the analogy is this—that by following it out we may some time or other come to understand how these diseases are propagated, just as we understand now all about fermentation; and that, in this way, some of the greatest scourges which afflict the human race may be, if not prevented, at least largely alleviated.

This is the conclusion of the statements which I wished to put before you. You see we have not been able to have any accessories. If you will come in such numbers to hear a lecture of this sort, all I can say is, that diagrams cannot be made big enough for you, and that it is not possible to show any experiments illustrative of a lecture on such a subject as I have to deal with. Of course my friends the chemists and physicists are very much better off, because they can not only show you experiments, but you can smell them and hear them! But in my case such aids are not attainable, and therefore I have taken a simple subject and have dealt with it in such a way that I hope you all understand it, at least so far as I have been able to put it before you in words; and having apprehended such of the ideas and simple facts of the case as it was possible to put before you, you can see for yourselves the great and wonderful issues of such an apparently homely subject.

QUESTIONS AND EXERCISES

This selection is an example of skill in presenting abstract scientific facts to an uninstructed audience in a clear and interesting manner. The text of this lecture as given in this book is probably a shorthand report. It will be found to differ in some particulars from the essay under the same title in Vol. VIII of Huxley's *Collected Essays*. This latter paper is probably the lecture revised and enlarged for publication.

1. Point out the steps by which Huxley leads his hearers from a standpoint of common knowledge to various unknown facts. What are the new topics? Do they seem carefully chosen in advance? Is the order in which they are brought forward logical? Is Huxley's method of presenting them usually indictive or deductive, that is, does he first mention a number of specific facts and then draw from them some general inference, or does he express a general opinion and then elucidate it by bringing forward specific illustrations?

2. Are the main divisions clearly distinguished? Find the important transitional and summarizing passages. What is the particular importance of such landmarks of structure in a popular lecture?

3. Are all the points in the lecture clear? In seeking to make his

knowledge generally intelligible, has Huxley sacrificed anywhere scientific accuracy?

4. In the light of the object and occasion of this lecture, what kind of words would it be proper for Huxley to use? Are any of the words unintelligible to you? Is the language at all technical? When Huxley finds it necessary to use an unfamiliar term, what precaution does he take to insure its comprehension?

5. Point out the devices used to make the lecture attractive to the listeners. What is accomplished by the introduction? Is the familiarity of tone as seen in conversational expletives and the use of the second person plural desirable in a popular lecture?

6. Compare this lecture with the essay *On Yeast*, in the writer's *Collected Essays*. What differences do you discover? Can you explain these differences by the fact that the one was for oral presentation, the other for publication in a magazine or book?

7. Examine other popular lectures of Huxley's, for instance, *On a Piece of Chalk*, or *On the Formation of Coal*. Is the method essentially the same as in this lecture?

8. Judging from the present instance, would the following criticism of Huxley's essays be true? "In form his essays are often rambling, sometimes disconnected, occasionally prolix. He plunges into the midst of a subject and, discovering there an almost limitless number of things which are apropos of the last thing he said, frequently skips about hither and thither, trusting to good luck and his own mother wit to guide him safely to some suitable conclusion." ("Huxley as a Literary Man," *Century Magazine*, Vol. LXIII, p. 392.)

Exercise 1. Prepare for an audience of laboring men a talk on one of the following topics. Before beginning to write decide: (1) to what extent you must limit your topic, that is, what technical details could not very well be comprehended by your audience and must consequently be omitted; (2) what illustrations will be most effective with such an audience. Watch carefully your vocabulary.

On the horse-shoe magnet.
On the action of baking-powder.
The lever.
On the formation of coal.
The uses of the wind.
On competition in trade.
The development of great underground caves.
The formation and movement of a glacier.
The origin and growth of a river valley.

The telegraph in theory and practice.
The relation between body and mind.
The disguises of insects.
The action of diphtheria antitoxin.
The liquefaction of air.
The undulatory theory of light.
Dialects: what they are and how they arise.
How to improve the quality of fruit.
The latent power in a rain-drop.

THE GROWTH OF SCIENCE IN THE NINETEENTH CENTURY [1]

SIR MICHAEL FOSTER, K.C.B.

THE eyes of the young look ever forward; they take little heed of the short though ever-lengthening fragment of life which lies behind them; they are wholly bent on that which is to come. The eyes of the aged turn wistfully again and again to the past; as the old glide down the inevitable slope, their present becomes a living over again the life which has gone before, and the future takes on the shape of a brief lengthening of the past. May I this evening venture to give rein to the impulses of advancing years? May I, at this last meeting of the association in the eighteen hundreds, dare to dwell for a while upon the past, and to call to mind a few of the changes which have taken place in the world since those autumn days in which men were saying to each other that the last of the seventeen hundreds was drawing toward its end?

Dover in the year of our Lord 1799 was in many ways unlike the Dover of to-day. On moonless nights men groped their way in its narrow streets by the help of swinging lanterns and smoky torches, for no lamps lit the ways. By day the light of the sun struggled into the houses through narrow panes of

[1] The President's address at the Dover meeting of the British Association for the Advancement of Science, 1899. Reprinted, with some abridgement, from the Report of the Association.

blurred glass. Though the town then, as now, was one of the chief portals to and from the countries beyond the seas, the means of travel was scanty and dear, available for the most part to the rich alone, and for all beset with discomfort and risk. Slow and uncertain was the carriage of goods, and the news of the world outside came to the town (though it, from its position, learnt more than most towns) tardily, fitfully, and often falsely. The people of Dover sat then much in dimness, if not in darkness, and lived in large measure on themselves. They who study the phenomena of living beings tell us that light is the great stimulus of life, and that the fulness of the life of a being or of any of its members may be measured by the variety, the swiftness, and the certainty of the means by which it is in touch with its surroundings. Judged from this standpoint, life at Dover then, as indeed elsewhere, must have fallen far short of the life of to-day.

The same study of living beings, however, teaches us that while from one point of view the environment seems to mold the organism, from another point the organism seems to be master of its environment. Going behind the change of circumstances, we may raise the question, the old question, Was life in its esssence worth more then than now? Has there been a real advance?

Let me at once relieve your minds by saying that I propose to leave this question in the main unanswered. It may be, or it may not be, that man's grasp of the beautiful and of the good, if not looser, is not firmer than it was a hundred years ago. It may be, or it may not be, that man is no nearer to absolute truth, to seeing things as they really are, than he was then. I will merely ask you to consider with me for a few minutes how far and in what ways man's laying hold of that aspect of or part of truth which we call natural knowledge, or sometimes science, differed in 1799 from what it is to-day, and whether that change must not be accounted a real advance, a real improvement in man.

I do not propose to weary you by what in my hands would be the rash effort of attempting a survey of all the scientific results

of the nineteenth century. It will be enough if for a little while I dwell on some few of the salient features distinguishing the way in which we nowadays look upon, and during the coming week shall speak of, the works of nature around us—though those works themselves, save for the slight shifting involved in a secular change, remain exactly the same—from the way in which they were looked upon and might have been spoken of at a gathering of philosophers at Dover in 1799, and I ask your leave to do so.

In the philosophy of the ancients earth, fire, air, and water were called "the elements." It was thought, and rightly thought, that a knowledge of them and of their attributes was a necessary basis of a knowledge of the ways of nature. Translated into modern language, a knowledge of these "elements" of old means a knowledge of the composition of the atmosphere, of water, and of all the other things which we call matter, as well as a knowledge of the general properties of gases, liquids, and solids, and of the nature and effects of combustion. Of all these things our knowledge to-day is large and exact, and, though ever enlarging, in some respects complete. When did that knowledge begin to become exact?

To-day the children in our schools know that the air which wraps round the globe is not a single thing, but is made up of two things, oxygen and nitrogen,[1] mingled together. They know, again, that water is not a single thing, but the product of two things, oxygen and hydrogen joined together. They know that when the air makes the fire burn and gives the animal life, it is the oxygen in it which does the work. They know that all round them things are undergoing that union with oxygen which we call oxidation, and that oxidation is the ordinary source of heat and light. Let me ask you to picture to yourselves what confusion there would be to-morrow, not only in the discussions at the sectional meetings of our association, but in the world at large, if it should happen that in the coming night some destroying touch should wither up certain tender structures in all our brains and wipe out from our memories

[1] Some may already know that there is at least a third thing, argon.

all traces of the ideas which cluster in our minds around the verbal tokens, oxygen and oxidation. How could any of us, not the so-called man of science alone, but even the man of business and the man of pleasure, go about his ways lacking those ideas? Yet those ideas were in 1799 lacking to all but a few.

Although in the third quarter of the seventeenth century the light of truth about oxidation and combustion had flashed out in the writings of John Mayow, it came as a flash only, and died away as soon as it had come. For the rest of that century, and for the greater part of the next, philosophers stumbled about in darkness, misled for the most of the time by the phantom conception which they called phlogiston. It was not until the end of the third quarter of the eighteenth century that the new light, which has burned steadily ever since, lit up the minds of the men of science. The light came at nearly the same time from England and from France. Rounding off the sharp corners of controversy, and joining, as we may fitly do to-day, the two countries as twin bearers of a common crown, we may say that we owe the truth to Priestley, to Lavoisier, and to Cavendish. If it was Priestley who was the first to demonstrate the existence of what we now call oxygen, it is to Lavoisier we owe the true conception of the nature of oxidation and the clear exposition of the full meaning of Priestley's discovery, while the knowledge of the composition of water, the necessary complement of the knowledge of oxygen, came to us through Cavendish and, we may perhaps add, through Watt.

The date of Priestley's discovery of oxygen is 1774, Lavoisier's classic memoir "On the nature of the principle which enters into combination with metals during calcination" appeared in 1775, and Cavendish's paper on the composition of water did not see the light until 1784.

During the last quarter of the eighteenth century this new idea of oxygen and oxidation was struggling into existence. How new was the idea is illustrated by the fact that Lavoisier himself at first spoke of that which he was afterwards, namely, in 1778, led to call oxygen, the name by which it has since been

known, as "the principle which enters into combination." What difficulties its acceptance met with is illustrated by the fact that Priestley himself refused to the end of his life to grasp the true bearings of the discovery which he had made. In the year 1799 the knowledge of oxygen, of the nature of water and of air, and indeed the true conception of chemical composition and chemical change, was hardly more than beginning to be, and the century had to pass wholly away before the next great chemical idea, which we know by the name of the atomic theory of John Dalton, was made known. We have only to read the scientific literature of the time to recognize that a truth which is now not only woven as a master thread into all our scientific conceptions, but even enters largely into the everyday talk and thoughts of educated people, was a hundred years ago struggling into existence among the philosophers themselves. It was all but absolutely unknown to the large world outside those select few.

If there be one word of science which is writ large on the life of the present time, it is the word "electricity." It is, I take it, writ larger than any other word. The knowledge which it denotes has carried its practical results far and wide into our daily life, while the theoretical conceptions which it signifies pierce deep into the nature of things. We are to-day proud, and justly proud, both of the material triumphs and of the intellectual gains which it has brought us, and we are full of even larger hopes of it in the future.

At what time did this bright child of the nineteenth century have its birth?

He who listened to the small group of philosophers of Dover, who in 1799 might have discoursed of natural knowledge, would perhaps have heard much of electric machines, of electric sparks, of the electric fluid, and even of positive and negative electricity; for frictional electricity had long been known and even carefully studied. Probably one or more of the group, dwelling on the observations which Galvani, an Italian, had made known some twenty years before, developed views on the connection of electricity with the phenomena of living

bodies. Possibly one of them was exciting the rest by telling how he had just heard that a professor at Pavia, one Volta, had discovered that electricity could be produced not only by rubbing together particular bodies, but by the simple contact of two metals, and had thereby explained Galvani's remarkable results. For, indeed, as we shall hear from Professor Fleming, it was in that very year, 1799, that electricity as we now know it took its birth. It was then that Volta brought to light the apparently simple truths out of which so much has sprung. The world, it is true, had to wait for yet some twenty years before both the practical and theoretic worth of Volta's discovery became truly pregnant under the fertilizing influence of another discovery. The loadstone and magnetic virtues had, like the electrifying power of rubbed amber, long been an old story. But, save for the compass, not much had come from it. And even Volta's discovery might have long remained relatively barren had it been left to itself. When, however, in 1819, Oersted made known his remarkable observations on the relations of electricity to magnetism, he made the contact needed for the flow of a new current of ideas. And it is perhaps not too much to say that those ideas, developing during the years of the rest of the century with an ever-accelerating swiftness, have wholly changed man's material relations to the circumstances of life, and at the same time carried him far in his knowledge of the nature of things.

Of all the various branches of science, none perhaps is to-day, none for these many years past has been, so well known to, even if not understood by, most people as that of geology. Its practical lessons have brought wealth to many; its fairy tales have brought delight to more; and round it hovers the charm of danger, for the conclusions to which it leads touch on the nature of man's beginning.

In 1799 the science of geology, as we now know it, was struggling into birth. There had been from of old cosmogonies, theories as to how the world had taken shape out of primeval chaos. In that fresh spirit which marked the zealous search after natural knowledge pursued in the middle and latter part of the seven-

teenth century, the brilliant Stenson, in Italy, and Hooke, in our own country, had laid hold of some of the problems presented by fossil remains, and Woodward, with others, had labored in the same field. In the eighteenth century, especially in its latter half, men's minds were busy about the physical agencies determining or modifying the features of the earth's crust; water and fire, subsidence from a primeval ocean and transformation by outbursts of the central heat, Neptune and Pluto, were being appealed to, by Werner on the one hand and by Demarest on the other, in explanation of the earth's phenomena. The way was being prepared, theories and views were abundant, and many sound observations had been made; and yet the science of geology, properly so called, the exact and proved knowledge of the successive phases of the world's life, may be said to date from the closing years of the eighteenth century.

In 1783 James Hutton put forward in a brief memoir his Theory of the Earth, which, in 1795, two years before his death, he expanded into a book; but his ideas failed to lay hold of men's minds until the century had passed away, when, in 1802, they found an able expositor in John Playfair. The very same year that Hutton published his theory, Cuvier came to Paris and almost forthwith began, with Brongniart, his immortal researches into the fossils of Paris and its neighborhood. And four years later, in the year 1799 itself, William Smith's tabular list of strata and fossils saw the light. It is, I believe, not too much to say that out of these geology, as we now know it, sprang. It was thus in the closing years of the eighteenth century that was begun the work which the nineteenth century has carried forward to such great results, but at this time only the select few had grasped the truth, and even they only the beginning of it. Outside a narrow circle the thoughts even of the educated about the history of the globe were bounded by the story of the deluge—though the story was often told in a strange fashion—or were guided by fantastic views of the plastic forces of a sportive nature.

In another branch of science, in that which deals with the problems presented by living beings, the thoughts of men in

1799 were also very different from the thoughts of men to-day. It is a very old quest, the quest after the knowledge of the nature of living beings, one of the earliest on which man set out; for it promised to lead him to a knowledge of himself, a promise which perhaps is still before us, but the fulfillment of which is yet far off. As time has gone on, the pursuit of natural knowledge has seemed to lead man away from himself into the furthermost parts of the universe, and into secret workings of Nature in which he appears to be of little or no account; and his knowledge of the nature of living things, and so of his own nature, has advanced slowly, waiting till the progress of other branches of natural knowledge can bring it aid. Yet in the past hundred years the biologic sciences, as we now call them, have marched rapidly onward.

We may look upon a living body as a machine doing work in accordance with certain laws, and may seek to trace out the working of the inner wheels, how these raise up the lifeless dust into living matter, and let the living matter fall away again into dust, giving out movement and heat. Or we may look upon the individual life as a link in a long chain, joining something which went before to something about to come, a chain whose beginning lies hid in the farthest past, and may seek to know the ties which bind one life to another. As we call up to view the long series of living forms, living now or flitting like shadows on the screen of the past, we may strive to lay hold of the influences which fashion the garment of life. Whether the problems of life are looked upon from the one point of view or the other, we to-day, not biologists only but all of us, have gained a knowledge hidden even from the philosophers a hundred years ago.

Of the problems presented by the living body viewed as a machine, some may be spoken of as mechanical, others as physical, and yet others as chemical, while some are, apparently at least, none of these. In the seventeenth century William Harvey, laying hold of the central mechanism of the blood stream, opened up a path of inquiry which his own age and the century which followed trod with marked success. The knowl-

edge of the mechanics of the animal and of the plant advanced apace, but the physical and chemical problems had yet to wait. The eighteenth century, it is true, had its physics and its chemistry; but, in relation at least to the problems of the living being, a chemistry which knew not oxygen and a physics which knew not the electricity of chemical action were of little avail. The philosopher of 1799, when he discussed the functions of the animal or of the plant involving chemical changes, was fain for the most part, as were his predecessors in the century before, to have recourse to such vague terms as "fermentation" and the like; to-day our treatises on physiology are largely made up of precise and exact expositions of the play of physical agencies and chemical bodies in the living organisms. He made use of the words "vital force" or "vital principle" not as an occasional, but as a common explanation of the phenomena of the living body. During the present century, especially during its latter half, the idea embodied in those words has been driven away from one seat after another; if we use it now when we are dealing with the chemical and physical events of life, we use it with reluctance, as a *deus ex machina* to be appealed to only when everything else has failed.

Some of the problems—and those, perhaps, the chief problems—of the living body have to be solved neither by physical nor chemical methods, but by methods of their own. Such are the problems of the nervous system. In respect to these the men of 1799 were on the threshold of a pregnant discovery. During the latter part of the present century, and especially during its last quarter, the analysis of the mysterious processes in the nervous system, and especially in the brain, which issue as feeling, thought, and the power to move, has been pushed forward with a success conspicuous in its practical, and full of promise in its theoretical, gains. That analysis may be briefly described as a following up of threads. We now know that what takes place along a tiny thread which we call a nerve fiber differs from that which takes place along its fellow-threads, that differing nervous impulses travel along different nervous fibers, and that nervous and psychical events are the outcome of the

clashing of nervous impulses as they sweep along the closely woven web of living threads of which the brain is made. We have learned by experiment and by observation that the pattern of the web determines the play of the impulses, and we can already explain many of the obscure problems not only of nervous disease, but of nervous life, by an analysis which is a tracking out the devious and linked path of nervous threads. The very beginning of this analysis was unknown in 1799. Men knew that nerves were the agents of feeling and of the movements of muscles; they had learned much about what this part or that part of the brain could do; but they did not know that one nerve fiber differed from another in the very essence of its work. It was just about the end of the past century, or the beginning of the present one, that an English surgeon began to ponder over a conception which, however, he did not make known until some years later, and which did not gain complete demonstration and full acceptance until still more years had passed away. It was in 1811, in a tiny pamphlet published privately, that Charles Bell put forth his New Idea that the nervous system was constructed on the principle that "the nerves are not single nerves possessing various powers, but bundles of different nerves whose filaments are united for the convenience of distribution, but which are distinct in office as they are in origin from the brain."

Our present knowledge of the nervous system is to a large extent only an exemplification and expansion of Charles Bell's New Idea, and has its origin in that.

If we pass from the problems of the living organism viewed as a machine to those presented by the varied features of the different creatures who have lived or who still live on the earth, we at once call to mind that the middle years of the present century mark an epoch in biologic thought such as never came before, for it was then that Charles Darwin gave to the world the Origin of Species.

That work, however, with all the far-reaching effects which it has had, could have had little or no effect, or, rather, could not

have come into existence, had not the earlier half of the century been in travail preparing for its coming. For the germinal idea of Darwin appeals, as to witnesses, to the results of two lines of biologic investigation which were almost unknown to the men of the eighteenth century.

To one of these lines I have already referred. Darwin, as we know, appealed to the geological record; and we also know how that record, imperfect as it was then, and imperfect as it must always remain, has since his time yielded the most striking proofs of at least one part of his general conception. In 1799 there was, as we have seen, no geological record at all.

Of the other line I must say a few words.

To-day the merest beginner in biologic study, or even that exemplar of acquaintance without knowledge, the general reader, is aware that every living being, even man himself, begins its independent existence as a tiny ball, of which we can, even acknowledging to the full the limits of the optical analysis at our command, assert with confidence that in structure, using that word in its ordinary sense, it is in all cases absolutely simple. It is equally well known that the features of form which supply the characters of a grown-up living being, all the many and varied features of even the most complex organism, are reached as the goal of a road, at times a long road, of successive changes; that the life of every being, from the ovum to its full estate, is a series of shifting scenes, which come and go, sometimes changing abruptly, sometimes melting the one into the other, like dissolving views, all so ordained that often the final shape with which the creature seems to begin, or is said to begin, its life in the world is the outcome of many shapes, clothed with which it in turn has lived many lives before its seeming birth.

All or nearly all the exact knowledge of the labored way in which each living creature puts on its proper shape and structure is the heritage of the present century. Although the way in which the chick is molded in the egg was not wholly unknown even to the ancients, and in later years had been told, first in the sixteenth century by Fabricius, then in the seventeenth century

in a more clear and striking manner by the great Italian naturalist, Malpighi, the teaching thus offered had been neglected or misinterpreted. At the close of the eighteenth century the dominant view was that in the making of a creature out of the egg there was no putting on of wholly new parts, no epigenesis. It was taught that the entire creature lay hidden in the egg, hidden by reason of the very transparency of its substance, lay ready-made, but folded up, as it were, and that the process of development within the egg or within the womb was a mere unfolding, a simple evolution. Nor did men shrink from accepting the logical outcome of such a view—namely, that within the unborn creature itself lay in like manner, hidden and folded up, its offspring also, and within that again its offspring in turn, after the fashion of a cluster of ivory balls carved by Chinese hands, one within the other. This was no fantastic view put forward by an imaginative dreamer; it was seriously held by sober men, even by men like the illustrious Haller, in spite of their recognizing that as the chick grew in the egg some changes of form took place. Though so early as the middle of the eighteenth century Friedrich Casper Wolff and, later on, others had strenuously opposed such a view, it held its own not only to the close of the century, but far on into the next. It was not until a quarter of the present century had been added to the past that Von Baer made known the results of researches which once and for all swept away the old view. He and others working after him made it clear that each individual puts on its final form and structure not by an unfolding of preëxisting hidden features, but by the formation of new parts through the continued differentiation of a primitively simple material. It was also made clear that the successive changes which the embryo undergoes in its progress from the ovum to maturity are the expression of morphologic laws, that the progress is one from the general to the special, and that the shifting scenes of embryonic life are hints and tokens of lives lived by ancestors in times long past.

If we wish to measure how far off in biologic thought the end of the last century stands, not only from the end, but even from

the middle of this one, we may imagine Darwin striving to write the Origin of Species in 1799. We may fancy him being told by philosophers explaining how one group of living beings differed from another group because all its members and all their ancestors came into existence at one stroke when the first-born progenitor of the race, within which all the rest were folded up, stood forth as the result of a creative act. We may fancy him listening to a debate between the philosopher who maintained that all the fossils strewn in the earth were the remains of animals or plants churned up in the turmoil of a violent universal flood, and dropped in their places as the waters went away, and him who argued that such were not really the "spoils of living creatures," but the products of some playful plastic power which out of the super-abundance of its energy fashioned here and there the lifeless earth into forms which imitated, but only imitated, those of living things. Could he amid such surroundings, by any flight of genius have beat his way to the conception for which his name will ever be known?

Here I may well turn away from the past. It is not my purpose, nor, as I have said, am I fitted, nor is this perhaps the place, to tell even in outline the tale of the work of science in the nineteenth century. I am content to have pointed out that the two great sciences of chemistry and geology took their birth, or at least began to stand alone, at the close of the last century, and have grown to be what we know them now within about a hundred years, and that the study of living beings has within the same time been so transformed as to be to-day something wholly different from what it was in 1799. And, indeed, to say more would be to repeat almost the same story about other things. If our present knowledge of electricity is essentially the child of the nineteenth century, so also is our present knowledge of many other branches of physics. And those most ancient forms of exact knowledge, the knowledge of numbers and of the heavens, whose beginning is lost in the remote past, have, with all other kinds of natural knowledge, moved onward during the whole of the hundred years with a speed which is ever increasing. I have said, I trust, enough to justify the statement

that in respect to natural knowledge a great gulf lies between 1799 and 1899. That gulf, moreover, is a twofold one: Not only has natural knowledge been increased, but men have run to and fro spreading it as they go. Not only have the few driven far back round the full circle of natural knowledge the dark clouds of the unknown which wrap us all about, but also the many walk in the zone of light thus increasingly gained. If it be true that the few to-day are, in respect to natural knowledge, far removed from the few of those days, it is also true that nearly all which the few alone knew then, and much which they did not know, has now become the common knowledge of the many.

What, however, I may venture to insist upon here is that the difference in respect to natural knowledge, whatever be the case with other differences between then and now, is undoubtedly a difference which means progress. The span between the science of that time and the science of to-day is beyond all question a great stride onward.

We may say this, but we must say it without boasting. For the very story of the past which tells of the triumphs of science bids the man of science put away from him all thoughts of vainglory, and that by many tokens.

Whoever, working at any scientific problem, has occasion to study the inquiries into the same problem made by some fellow-worker in the years long gone by, comes away from that study humbled by one or other of two different thoughts. On the one hand, he may find, when he has translated the language of the past into the phraseology of to-day, how near was his forerunner of old to the conception which he thought, with pride, was all his own, not only so true but so new. On the other hand, if the ideas of the investigator of old, viewed in the light of modern knowledge, are found to be so wide of the mark as to seem absurd, the smile which begins to play upon the lips of the modern is checked by the thought, Will the ideas which I am now putting forth, and which I think explain so clearly, so fully the problem in hand, seem to some worker in the far future as wrong and as fantastic as do these of my forerunner to me?

In either case his personal pride is checked. Further, there is written clearly on each page of the history of science, in characters which can not be overlooked, the lesson that no scientific truth is born anew, coming by itself and of itself. Each new truth is always the offspring of something which has gone before, becoming in turn the parent of something coming after. In this aspect the man of science is unlike, or seems to be unlike, the poet and the artist. The poet is born, not made; he rises up, no man knowing his beginnings; when he goes away, though men after him may sing his songs for centuries, he himself goes away wholly, having taken with him his mantle, for this he can give to none other. The man of science is not thus creative; he is created. His work, however great it be, is not wholly his own; it is in part the outcome of the work of men who have gone before. Again and again a conception which has made a name great has come not so much by the man's own effort as out of the fullness of time. Again and again we may read in the words of some man of old the outlines of an idea which in later days has shone forth as a great acknowledged truth. From the mouth of the man of old the idea dropped barren, fruitless; the world was not ready for it, and heeded it not; the concomitant and abutting truths which could give it power to work were wanting. Coming back again in later days, the same idea found the world awaiting it; things were in travail preparing for it, and some one, seizing the right moment to put it forth again, leaped into fame. It is not so much the men of science who make science as some spirit which, born of the truths already won, drives the man of science onward and uses him to win new truths in turn.

It is because each man of science is not his own master, but one of many obedient servants of an impulse which was at work long before him, and will work long after him, that in science there is no falling back. In respect to other things there may be times of darkness and times of light; there may be risings, decadences, and revivals. In science there is only progress. The path may not be always a straight line; there may be swerving to this side and to that; ideas may seem to return

again and again to the same point of the intellectual compass; but it will always be found that they have reached a higher level—they have moved, not in a circle, but in a spiral. Moreover, science is not fashioned as is a house, by putting brick to brick, that which is once put remaining as it was put to the end. The growth of science is that of a living being. As in the embryo, phase follows phase, and each member or body puts on in succession different appearances, though all the while the same member, so a scientific conception of one age seems to differ from that of a following age, though it is the same one in the process of being made; and as the dim outlines of the early embryo become, as the being grows more distinct and sharp, like a picture on a screen brought more and more into focus, so the dim gropings and searchings of the men of science of old are by repeated approximations wrought into the clear and exact conclusions of later times.

The story of natural knowledge, of science, in the nineteenth century, as, indeed, in preceding centuries, is, I repeat, a story of continued progress. There is in it not so much as a hint of falling back, not even of standing still. What is gained by scientific inquiry is gained forever; it may be added to, it may seem to be covered up, but it can never be taken away. Confident that the progress will go on, we can not help peering into the years to come and straining our eyes to foresee what science will become and what it will do as they roll on. While we do so, the thought must come to us, Will all the increasing knowledge of nature avail only to change the ways of man; will it have no effect on man himself?

The material good which mankind has gained and is gaining through the advance of science is so imposing as to be obvious to everyone, and the praises of this aspect of science are to be found in the mouths of all. Beyond all doubt science has greatly lessened and has markedly narrowed hardship and suffering; beyond all doubt science has largely increased and has widely diffused ease and comfort. The appliances of science have, as it were, covered with a soft cushion the rough places of life, and that not for the rich only, but also for the poor. So abun-

dant and so prominent are the material benefits of science that in the eyes of many these seem to be the only benefits which she brings. She is often spoken of as if she were useful and nothing more, as if her work were only to administer to the material wants of man.

Is this so?

We may begin to doubt it when we reflect that the triumphs of science which bring these material advantages are in their very nature intellectual triumphs. The increasing benefits brought by science are the results of man's increasing mastery over nature, and that mastery is increasingly a mastery of mind; it is an increasing power to use the forces of what we call inanimate nature in place of the force of his own or other creatures' bodies; it is an increasing use of mind in place of muscle.

Is it to be thought that that which has brought the mind so greatly into play has had no effect on the mind itself? Is that part of the mind which works out scientific truths a mere slavish machine, producing results it knows not how, having no part in the good which in its workings it brings forth?

What are the qualities, the features, of that scientific mind which has wrought, and is working, such great changes in man's relation to nature? In seeking an answer to this question we have not to inquire into the attributes of genius. Though much of the progress of science seems to take on the form of a series of great steps, each made by some great man, the distinction in science between the great discoverer and the humble worker is one of degree only, not of kind. As I was urging just now, the greatness of many great names in science is often, in large part, the greatness of occasion, not of absolute power. The qualities which guide one man to a small truth silently taking its place among its fellows, as these go to make up progress, are at bottom the same as those by which another man is led to something of which the whole world rings.

The features of the fruitful scientific mind are in the main three.

In the first place, above all other things, his nature must be one which vibrates in unison with that of which he is in search;

the seeker after truth must himself be truthful, truthful with the truthfulness of nature. For the truthfulness of nature is not wholly the same as that which man sometimes calls truthfulness. It is far more imperious, far more exacting. Man, unscientific man, is often content with "the nearly" and "the almost." Nature never is. It is not her way to call the same two things which differ, though the difference may be measured by less than a thousandth of a milligram or of a millimeter, or by any other like standard of minuteness. And the man who, carrying the ways of the world into the domain of science, thinks that he may treat nature's differences in any other way than she treats them herself, will find that she resents his conduct; if he, in carelessness or in disdain, overlooks the minute difference which she holds out to him as a signet to guide him in his search, the projecting tip, as it were, of some buried treasure, he is bound to go astray, and the more strenuously he struggles on the farther he will find himself from his true goal.

In the second place, he must be alert of mind. Nature is ever making signs to us; she is ever whispering to us the beginnings of her secrets; the scientific man must be ever on the watch, ready at once to lay hold of nature's hint, however small; to listen to her whisper, however low.

In the third place, scientific inquiry, though it be preëminently an intellectual effort, has need of the moral quality or courage—not so much the courage which helps a man to face a sudden difficulty as the courage of steadfast endurance. Almost every inquiry, certainly every prolonged inquiry, sooner or later goes wrong. The path, at first so straight and clear, grows crooked and gets blocked; the hope and enthusiasm, or even the jaunty ease, with which the inquirer set out, leave him, and he falls into a slough of despond. That is the critical moment calling for courage. Struggling through the slough, he will find on the other side the wicket gate opening up the real path; losing heart, he will turn back and add one more stone to the great cairn of the unaccomplished.

But, I hear some one say, these qualities are not the peculiar attributes of the man of science; they may be recognized as

belonging to almost everyone who has commanded or deserved success, whatever may have been his walk of life. That is so. That is exactly what I would desire to insist, that the men of science have no peculiar virtues, no special powers. They are ordinary men, their characters are common, even commonplace. Science, as Huxley said, is organized common sense, and men of science are common men drilled in the ways of common sense. For their life has this feature. Though in themselves they are no stronger, no better than other men, they possess a strength which, as I just now urged, is not their own, but is that of the science whose servants they are. Even in his apprenticeship the scientific inquirer, while learning what has been done before his time, if he learns it aright, so learns it that what is known may serve him not only as a vantage ground whence to push off into the unknown, but also as a compass to guide him in his course. And when fitted for his work he enters on inquiry itself, what a zealous, anxious guide, what a strict and, because strict, helpful schoolmistress does Nature make herself to him! Under her care every inquiry, whether it bring the inquirer to a happy issue or seem to end in naught, trains him for the next effort. She so orders her ways that each act of obedience to her makes the next act easier for him, and step by step she leads him on toward that perfect obedience which is complete mastery.

Indeed, when we reflect on the potency of the discipline of scientific inquiry we cease to wonder at the progress of scientific knowledge. The results actually gained seem to fall so far short of what under such guidance might have been expected to have been gathered in that we are fain to conclude that science has called to follow her, for the most part, the poor in intellect and the wayward in spirit. Had she called to her service the many acute minds who have wasted their strength struggling in vain to solve hopeless problems, or who have turned their energies to things other than the increase of knowledge; had she called to her service the many just men who have walked straight without the need of a rod to guide them, how much greater than it has been would have been the progress of science, and how

many false teachings would the world have been spared! To men of science themselves, when they consider their favored lot, the achievements of the past should serve not as a boast, but as a reproach.

If there be any truth in what I have been urging, that the pursuit of scientific inquiry is itself a training of special potency, giving strength to the feeble and keeping in the path those who are inclined to stray, it is obvious that the material gains of science, great as they may be, do not make up all the good which science brings or may bring to man. We especially, perhaps, in these later days, through the rapid development of the physical sciences, are too apt to dwell on the material gains alone. As a child in its infancy looks upon its mother only as a giver of good things, and does not learn till in after days how she was also showing her love by carefully training it in the way it should go, so we, too, have thought too much of the gifts of science, overlooking her power to guide.

Man does not live by bread alone, and science brings him more than bread. It is a great thing to make two blades of grass grow where before one alone grew; but it is no less great a thing to help a man to come to a just conclusion on the questions with which he has to deal. We may claim for science that while she is doing the one she may be so used as to do the other also. The dictum just quoted, that science is organized common sense, may be read as meaning that the common problems of life which common people have to solve are to be solved by the same methods by which the man of science solves his special problems. It follows that the training which does so much for him may be looked to as promising to do much for them. Such aid can come from science on two conditions only. In the first place, this her influence must be acknowledged; she must be duly recognized as a teacher no less than as a hewer of wood and a drawer of water. And the pursuit of science must be followed, not by the professional few only, but at least in such measure as will insure the influence of example by the many. But this latter point I need not urge before this great association, whose chief object during more than half a century has

been to bring within the fold of science all who would answer to the call. In the second place, it must be understood that the training to be looked for from science is the outcome, not of the accumulation of scientific knowledge, but of the practice of scientific inquiry. Man may have at his fingers' ends all the accomplished results and all the current opinions of any one or of all the branches of science, and yet remain wholly unscientific in mind; but no one can have carried out even the humblest research without the spirit of science in some measure resting upon him. And that spirit may in part be caught even without entering upon an actual investigation in search of a new truth. The learner may be led to old truths, even the oldest, in more ways than one. He may be brought abruptly to a truth in its finished form, coming straight to it like a thief climbing over the wall; and the hurry and press of modern life tempt many to adopt this quicker way. Or he may be more slowly guided along the path by which the truth was reached by him who first laid hold of it. It is by this latter way of learning the truth, and by this alone, that the learner may hope to catch something at least of the spirit of the scientific inquirer.

This is not the place, nor have I the wish, to plunge into the turmoil of controversy; but if there be any truth in what I have been urging, then they are wrong who think that in the schooling of the young science can be used with profit only to train those for whom science will be the means of earning their bread. It may be that from the point of view of pedagogic art the experience of generations has fashioned out of the older studies of literature an instrument of discipline of unusual power, and that the teaching of science is as yet but a rough tool in unpracticed hands. That, however, is not an adequate reason why scope should not be given for science to show the value which we claim for it as an intellectual training fitted for all sorts and conditions of men. Nor need the studies of humanity and literature fear her presence in the schools, for if her friends maintain that the teaching is one-sided, and therefore misleading, which deals with the doings of man only, and is silent about the works of nature, in the sight of which he and his doings

shrink almost to nothing, she herself would be the first to admit that that teaching is equally wrong which deals only with the works of nature and says nothing about the doings of man, who is, to us at least, nature's center.

There is yet another general aspect of science on which I would crave leave to say a word. In that broad field of human life which we call politics, in the struggle not of man with man, but of race with race, science works for good. If we look only on the surface it may at first sight seem otherwise. In no branch of science has there during these later years been greater activity and more rapid progress than in that which furnishes the means by which man brings death, suffering, and disaster on his fellowmen. If the healer can look with pride on the increased power which science has given him to alleviate human suffering and ward off the miseries of disease, the destroyer can look with still greater pride on the power which science has given him to sweep away lives and to work desolation and ruin; while the one has slowly been learning to save units, the other has quickly learned to slay thousands. But, happily, the very greatness of the modern power of destruction is already becoming a bar to its use, and bids fair—may we hope before long—wholly to put an end to it; in the words of Tacitus, though in another sense, the very preparations for war, through the character which science gives them, make for peace.

Moreover, not in one branch of science only, but in all, there is a deep undercurrent of influence sapping the very foundations of all war. As I have already urged, no feature of scientific inquiry is more marked than the dependence of each step forward on other steps which have been made before. The man of science can not sit by himself in his own cave weaving out results by his own efforts, unaided by others, heedless of what others have done and are doing. He is but a bit of a great system, a joint in a great machine, and he can only work aright when he is in due touch with his fellow workers. If his labor is to be what it ought to be, and is to have the weight which it ought to have, he must know what is being done, not by himself, but by others, and by others not of his own land and speak-

ing his tongue only, but also of other lands and of other speech. Hence it comes about that to the man of science the barriers of manners and of speech which pen men into nations become more and more unreal and indistinct. He recognizes his fellow-worker, wherever he may live, and whatever tongue he may speak, as one who is pushing forward shoulder to shoulder with him toward a common goal, as one whom he is helping and who is helping him. The touch of science makes the whole world kin.

The history of the past gives us many examples of this brotherhood of science. In the revival of learning throughout the sixteenth and seventeenth centuries, and some way on into the eighteenth century, the common use of the Latin tongue made intercourse easy. In some respects in those earlier days science was more cosmopolitan than it afterwards became. In spite of the difficulties and hardships of travel, the men of science of different lands again and again met each other face to face, heard with their ears, and saw with their eyes what their brethren had to say or show. The Englishman took the long journey to Italy to study there; the Italian, the Frenchman, and the German wandered from one seat of learning to another; and many a man held a chair in a country not his own. There was help, too, as well as intercourse. The Royal Society of London took upon itself the task of publishing nearly all the works of the great Italian, Malpighi, and the brilliant Lavoisier, two years before his own countrymen in their blind fury slew him, received from the same body the highest token which it could give of its esteem.

In these closing years of the nineteenth century this great need of mutual knowledge and of common action felt by men of science of different lands is being manifest in a special way. Though nowadays what is done anywhere is soon known everywhere, the news of a discovery being often flashed over the globe by telegraph, there is an increasing activity in the direction of organization to promote international meetings and international coöperation. In almost every science inquirers from many lands now gather together at stated intervals in inter-

national congresses to discuss matters which they have in common at heart, and go away each one feeling strengthened by having met his brother. The desire that in the struggle to lay bare the secrets of nature the least waste of human energy should be incurred is leading more and more to the concerted action of nations combining to attack problems the solution of which is difficult and costly. The determination of standards of measurement, magnetic surveys, the solution of great geodetic problems, the mapping of the heavens and of the earth—all these are being carried on by international organizations.

In this and in other countries men's minds have this long while past been greatly moved by the desire to make fresh efforts to pierce the dark secrets of the forbidding Antarctic regions. Belgium has just made a brave single-handed attempt; a private enterprise sailing from these shores is struggling there now, lost for the present to our view; and this year we in England and our brethren in Germany are, thanks to the promised aid of the respective governments, and no less to private liberality, in which this association takes its share, able to begin the preparation of carefully organized expeditions. That international amity of which I am speaking is illustrated by the fact that in this country and in that there is not only a great desire but a firm purpose to secure the fullest coöperation between the expeditions which will leave the two shores. If in this momentous attempt any rivalry be shown between the two nations, it will be for each a rivalry, not in forestalling, but in assisting the other. May I add that if the story of the past may seem to give our nation some claim to the seas as more peculiarly our own, that claim bespeaks a duty likewise peculiarly our own, to leave no effort untried by which we may plumb the seas' yet unknown depths and trace their yet unknown shores? That claim, if it means anything, means that when nations are joining hands in the dangerous work of exploring the unknown South, the larger burden of the task should fall to Britain's share; it means that we in this country should see to it, and see to it at once, that the concerted Antarctic expedition which in some two years or so will leave the shores of Ger-

many, of England, and perhaps of other lands, should, so far as we are concerned, be so equipped and so sustained that the risk of failure and disaster may be made as small, and the hope of being able not merely to snatch a hurried glimpse of lands not yet seen, but to gather in with full hands a rich harvest of the facts which men not of one science only, but of many, long to know, as great as possible.

Another international scientific effort demands a word of notice. The need which every inquirer in science feels to know, and to know quickly, what his fellow-worker, wherever on the globe he may be carrying on his work or making known his results, has done or is doing, led some four years back to a proposal for carrying out by international coöperation a complete current index, issued promptly, of the scientific literature of the world. Though much labor in many lands has been spent upon the undertaking, the project is not yet an accomplished fact. Nor can this, perhaps, be wondered at, when the difficulties of the task are weighed. Difficulties of language, difficulties of driving in one team all the several sciences which, like young horses, wish each to have its head free with leave to go its own way, difficulties mechanical and financial, of press and post, difficulties raised by existing interests—these and yet other difficulties are obstacles not easy to be overcome. The most striking and the most encouraging features of the deliberations which have now been going on for three years have been the repeated expressions, coming not from this or that quarter only, but from almost all quarters, of an earnest desire that the effort should succeed, of a sincere belief in the good of international coöperation, and of a willingness to sink as far as possible individual interests for the sake of the common cause. In the face of such a spirit we may surely hope that the many difficulties will ultimately pass out of sight.

Perhaps, however, not the least notable fact of international coöperation in science is the proposal which has been made within the last two years that the leading academies of the world should, by representatives, meet at intervals to discuss questions in which the learned of all lands are interested. A

month hence a preliminary meeting of this kind will be held at Wiesbaden; and it is at least probable that the closing year of that nineteenth century in which science has played so great a part may at Paris during the great World's Fair—which every friend, not of science only, but of humanity, trusts may not be put aside or even injured through any untoward event, and which promises to be an occasion not of pleasurable sight-seeing only, but also, by its many international congresses, of international communing in the search for truth—witness the first select Witenagemote of the science of the world.

I make no apology for having thus touched on international coöperation. I should have been wanting had I not done so on the memorable occasion of this meeting. A hundred years ago two great nations were grappling with each other in a fierce struggle which had lasted, with pauses, for many years, and which was to last for many years to come; war was on every lip and in almost every heart. To-day this meeting has, by a common wish, been so arranged that those two nations should, in the persons of their men of science, draw as near together as they can, with nothing but the narrow streak of the channel between them, in order that they may take counsel together on matters in which they have one interest and a common hope. May we not look upon this brotherly meeting as one of many signs that science, though she works in a silent manner and in ways unseen by many, is steadily making for peace?

Looking back, then, in this last year of the eighteen hundreds, on the century which is drawing to a close, while we may see in the history of scientific inquiry much which, telling the man of science of his shortcomings and his weakness, bids him be humble, we also see much, perhaps more, which gives him hope. Hope is, indeed, one of the watchwords of science. In the latter-day writings of some who know not science much may be read which shows that the writer is losing or has lost hope in the future of mankind. There are not a few of these; their repeated utterances make a sign of the times. Seeing in matters lying outside science few marks of progress and many tokens of decline or decay, recognizing in science its material benefits

only, such men have thoughts of despair when they look forward to the times to come. But if there be any truth in what I have attempted to urge to-night, if the intellectual, if the moral influences of science are no less marked than her material benefits, if, moreover, that which she has done is but the earnest of that which she shall do, such men may pluck up courage and gather strength by laying hold of her garment. We men of science at least need not share their views or their fears. Our feet are set, not on the shifting sands of the opinions and of the fancies of the day, but on a solid foundation of verified truth, which by the labors of each succeeding age is made broader and more firm. To us the past is a thing to look back upon, not with regret, not as something which has been lost never to be regained, but with content, as something whose influence is with us still, helping us on our further way. With us, indeed, the past points not to itself, but to the future; the golden age is in front of us, not behind us; that which we do know is a lamp whose brightest beams are shed into the unknown before us, showing us how much there is in front and lighting up the way to reach it. We are confident in the advance because, as each one of us feels that any step forward which he may make is not ordered by himself alone and is not the result of his own sole efforts in the present, but is, and that in large measure, the outcome of the labors of others in the past, so each one of us has the sure and certain hope that as the past has helped him, so his efforts, be they great or be they small, will be a help to those to come.

QUESTIONS AND EXERCISES

The several examples heretofore given of the clear and detailed explanation of a single idea have dealt with the phenomena of science. They have therefore had their origin in observed facts, and these facts have in turn been brought under certain general principles. These principles have been explained by the writers of these selections. The present selection, however, is an example of the same thoroughness of treatment and carefulness of explanation applied to more abstract and intangible material.

1. Express briefly in a sentence the main thought of the selection. Prepare a full outline of it, showing main divisions and subdivisions.

2. How far has the writer succeeded in giving completeness to his treatment in the somewhat narrow limits of the time customarily allowed for such addresses? Point out places where he seems tempted to expand his discussion but refrains from doing so.

3. Is each topic presented clearly and distinctly in the course of the discussion? Does the conclusion leave the main point of the piece impressed upon the reader?

4. What is the value, so far as interest is concerned, of the comparison between the Dover of 1799 and that of 1899?

5. Explain the emphasizing value of the short, one-sentence paragraphs occurring in this piece.

6. How does the view of Sir Michael Foster on the value of education in science compare with that of John Stuart Mill as given in the selection on p. 125ff.?

Exercise 1. Write a composition of 600–800 words upon one of the following topics, or upon some similar subject.

Engineering feats of the past quarter-century.
Advances in geographical knowledge since 1492.
The progress of invention in the nineteenth century.
Growth of socialism within the last decade.
The spread of prohibition.
Old and recent methods of steam engine practice.
What has been added to the general stock of physical knowledge during the last ten years?

Exercise 2. Give a brief account of the advances in some particular science—chemistry, botany, pyschology, astronomy, etc.—during the nineteenth century.

MAKING CLEAR AND CONCRETE VERY SUBTLE IDEAS

COLOR-BLINDNESS [1]

EDWARD A. AYERS

IF one thousand men gaze at a garden of flowers, fifty of them will see the colors falsely. If one thousand women view them, nine hundred and ninety-six or -seven will perceive the hues correctly. Of the six colors of the rainbow which, mingled in thousands of combinations, give all the varying hues of sky and sea, of mountain and valley, some are never seen by the color-blind, or are felt only as light and shade of black and white. Very few persons are totally color-blind, yellow, blue, and violet being rarely lost. To the totally color-blind all landscapes and objects are like an engraving in black and white.

It is interesting to know why some eyes are color-blind, but it is more interesting to learn why any eyes see color at all. The photographic camera is so similar to the eye as a mechanical device that Nature might easily prove infringement of patent if she were less broad-minded. The camera focuses a scene upon a flat plate of ground glass, the eye upon a hemispherical membrane lining the posterior half of the ball. The camera gets a focus by sliding the glass forward or backward, the eye by thickening or flattening an elastic lens. The camera produces a picture when a sensitized plate has been exposed at focus—the negative. This gradation of light and shade can be etched into metal. The eye can make a permanent picture upon the sensitive plate—the retina—which can be "fixed"

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(a possibility that is useless, as it requires destruction of the eye); but in its daily work it runs far and away ahead of the camera. It sends "positive" pictures to the brain, *moving* and *in colors;* and with two eyes sends two pictures to two brains, the left and right halves, showing a little more than half of a spherical object, as shown in a stereopticon. It is true that the shops turn out many badly constructed eyes, with their long sight and their short sight, their uneven setting in the skull, and their lack of perfect sphericity, which causes such trouble that nothing short of "dextral or sinistral hypermetropic astigmatism" can properly designate it; yet when they leave the shops they are wound up to run automatically for threescore, fourscore or over a hundred years, according to the pleasure of Father Time.

The eye as a camera possesses a cap in its lids, which regulates the amount of light and the width of view that may reach the pupil. In its iris (a rainbow) it has an adjustable diaphragm that makes the pupil large in the shadows of eventide and small in the light of the sun, that its sensitive plate, the retina, may do its work without strain. Behind the pupil lies a transparent double convex lens which can be thickened for the short-focus needs of reading, or flattened for the distant gaze.

To the owl, with his great black pupil, the ordinary light of day is a brilliant glare against which his dazzled eyes prefer to draw the curtain of the lid; but the darkened recesses of the night are to him as the twilight is to man. If we look into his pupils, we shall see a red object. This is the retina, and it is upon this marvelous nerve structure in man that we need to throw a comprehensive light. It is, in fact, a portion of the brain, an aide-de-camp of the master mind stationed at one of its outer portals.

Arising from the base of the brain is a cable of nerve "wires," —the optic nerve,—which enters the eyeball, and then spreads out its many wires upon the inner surface of the posterior half of the eyeball. Retina means net. In Figures I and II are shown a highly simplified suggestion of its general construction. As the cable of nerve wires enters the eyeball, it may be said to con-

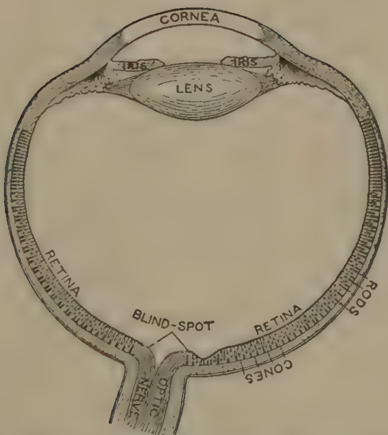

FIG. I.—SECTIONAL VIEW OF THE HUMAN EYE

The structure of the retina is here greatly simplified

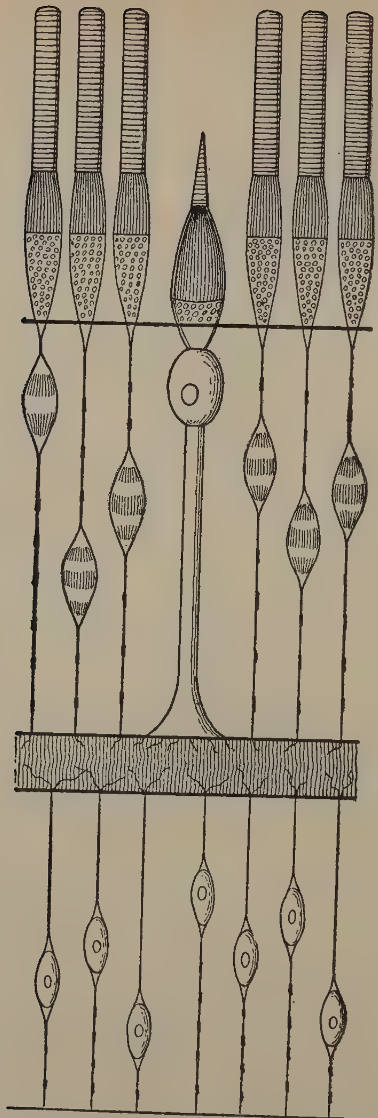

Fig. II.—Diagram showing Six Rods and One Cone of the Retina highly Simplified and Enlarged

tain 130,000,000 silver and 7,000,000 gold threads. The gold threads are mostly in the central portion of the cable. When these millions of threads are spread out after entering the eyeball, the master mechanic attaches to each of the silver threads a needle of glass, and to each of the threads of gold a pin of glass (the needle's real name is "rod," and the pin is called a "cone"), and sticks them into the hollowed hemisphere. What a pincushion! One hundred and thirty-seven million needles and pins in a cushion that could be covered by a silver quarter, and each "wired" to the brain through a cable as small as a slate-pencil. No wonder somebody christened this network "retina." Like Adam's pig, it would have been known as such without naming.

Transparent throughout, these rods and cones are bathed in the marshaled rays of light and color which pierce the window of the eye, and in this lambent, vibratory bath there lies the mystery of sight. Coursing throughout this mazy labyrinth are delicate blood-vessels the scarlet stream of which is almost transparent in so shallow a bed. If we gaze upon the sky with steady eyes, we can see the amber stream carrying its corpuscular freight like so many pieces of gold hither and thither. No rays of light can penetrate the cavity of the eye except through the pupil. The cavity behind the lens is filled with a transparent fluid called the vitreous humor, which chiefly serves to keep the eyeball expanded and to support the retina. The master mechanic, having now put his machine together, next pours a mysterious fluid in among the multi-million needle-rods, which has the peculiar chemical function of becoming purple in the darkness of sleep and of bleaching white when bathed in light. When the eye looks upon a landscape, the identical scene is pictured upon the retina just as a lantern throws a scene upon the screen, or the camera upon the ground glass. If we take the eye of an owl and look through it at a window, we shall see an inverted image of the window scene upon the translucent retina. If such a retina, after brief "exposure," be placed in a solution of potassium alum four per cent., this picture can be permanently "fixed." Photographs have

been made from the beetle's eye, which is like a hemisphere of glass side walk, with every glass a lens.

Thus far our little journey into the realms of the visible world has been over highways with plainly marked sign-posts; but now that we reach the question of how the retina can send to the brain such information that in its "visual chambers" the brain can *behold* the outer world in all its light and shade, clearness and simplicity become somewhat difficult.

There is a blind spot in every retina at the place of egress of the optic nerve. And there is a blind spot in the eye of science when it tries to throw a clear light upon the processes by which the brain receives impressions from eye, ear, nose, and tongue; receiving them all in the form of *waves of vibration*, translating each into a special language which the polyglot brain can understand. The key-note of it all lies in *the translation of vibratory waves;* in the capacity of brain cells to note rhythmic variations so marvelous in their speed, harmony, sequence, and individuality that the mind as a unit cannot grasp their intricacies. We can see the great waves of the sea uplift the mighty ship, or the widening circle as the pebble is thrown into the placid pool; we can observe the heat waves as they rise from the meadows sweltering in the midsummer sun; we can seem to understand the slow waves of sound as they roll from the organ's double-bass—waves that rattle the window-pane; and we can feel the painful impact of the cannon's roar; but we can form no picture of the waves of light as they travel 186,000 miles a second. Nor can we understand how the rods and cones of the retina can recognize the myriad differences of light, shade, and color, nor how the brain's secretary of sight can translate them into a picture replete with realism. Its mystery lies locked in the strong box of Nature, with those of telegraphy, phonography, telephony, and wireless telegraphy.

Let us bear in mind the difference between vibratory and transportation waves. A tidal wave is the genuine advance of a body of water through space. The waves of the wind are a genuine advance of air from one region to another; but ordinary sea-waves are almost wholly an up-and-down motion of the

surface water. A carpet shaken on the lawn shows undulatory waves which rapidly run from the shaker's hands, but there is no change in the carpet's position on the lawn. Waves of light, of sound, of smell, and of taste are all vibratory, and represent only a jostling of the medium, whether it be ether, air, water, earth, electricity, or nerve substance.

If a ray of light from the sun strike the eye, it will appear to be white. If such a ray be passed through a prism, it will spread out into a band of six colors: violet, blue, green, yellow, orange, and red. If these colors be repassed through a double convex lens, they will be re-combined into a white light. Black is the absence of all color; it absorbs all color. White is a compound of two or more colors. Such spectral colors as, combined, make a gray, or shade of white, are called "complementary colors." They are: violet with yellow-green, blue with yellow, green with purple, orange with green, and red with blue-green. In pigments which are not pure this may not apply. Blue and yellow make green. This point is of importance in its application to painting by color-blind artists.

The retina nerves—the rods and cones, and the brain cells in the visual center—are able to distinguish all color shades by the character of their vibrations, just as the ear knows the sound of a horn from that of a violin by the quality of the tone produced. In this respect the retina and the brain center of sight are smarter than the brain as a whole, the less is greater than the whole, the secretary is a better accountant than his employer. The master brain is at the mercy of its sight secretaries. In the retina, in its relations to sense of color, lie some of the most remarkable, puzzling, fascinating, beautiful, and unsolved phenomena ever studied.

The most satisfactory and plausible theory of color vision is that the rods and cones are the special nerve fibrils which interpret the vibrations of light and color; that the rods (needles) interpret light in its purely luminous phase (the quantity of white without regard to color) that the cones (pins) interpret colors, and distinguish them by the length of their respective waves; and that the many shades which are the products of

mixed colors are likewise recognized by the lengthening or shortening of the wave-lengths. There is a definite length to the vibration waves of the six primary colors. Red, the longest, is $\frac{1}{36000}$ of an inch in length; and violet, the shortest, $\frac{1}{61000}$ of an inch. If a note is sounded on a violin held near an open piano, it will cause the string to the piano which has the same number of vibrations per second—has the same pitch—to sound the same note. So there may be retinal cones which respond to each color wave's individual vibration. When the eyes gaze upon a pure red, 481,000,000,000 waves will beat upon the retinal shores in a second. Change the color to violet, and 764,000,000,000 waves will rush through the open window of the eye. Wonderful vibrations, wonderful mathematics! Between these two extremes, representing 283,000,000,000 different rates of speed, lie all the colors of the rainbow, and by those vibrations must the eye detect each shade. There are 4000 waves per second in the vibrations of the highest string on a piano, and each wave is three and one third inches long; whereas there are 61,000 violet waves in one inch. We can "think" of slow sound waves, but the brain gets overheated trying to follow the waves of light.

What remarkable sensitiveness the retinal nerves must possess, and yet silver and platinum "nerves" are far more sensitive. The eye can see only twenty odd per cent. of the color waves that fly through space. We are all totally color-blind to the remainder. All waves that are longer than 36,000 to the inch (red), or shorter than 61,000 to the inch (violet), are invisible. As shown in Figure III, there are waves longer than the red, called infra-red, unknown, and electric; and waves shorter than the violet, called ultra-violet, and Roentgen rays, which may be defined in musical analogy as covering three octaves, leaving about seven-eighths of an octave for the six colors which we can see. Our eyes are to the color scale of nature as the child with its toy piano is to master musician with a concert grand. Through the fluoroscope, which retards the speed, the eye can see some of the ultra-violet rays; and the infra-red rays can be felt as heat.

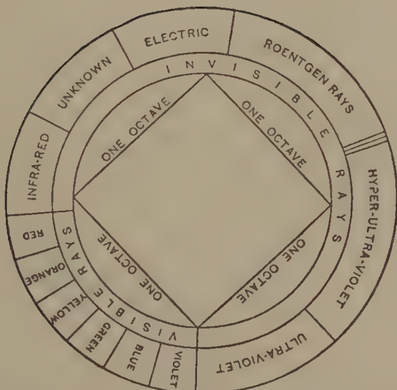

FIG. III.—DIAGRAM SHOWING THE PROPORTION OF VISIBLE TO INVISIBLE COLORS

The eye can see less than one-fourth of all. Recent opinion extends the invisible rays to nine octaves

There are two kinds of light waves emitted from all objects: color and white waves. Whenever a source of light, as the sun, strikes an object, part of that light is absorbed and part reflected—thrown back. The latter represents such object's "luminosity." The color-blind are never blind to this form of light. A mirror reflects almost all the light that falls upon it. Polished silver reflects ninety-two per cent. of perpendicular rays.

Broken surfaces split up such light, and so appear dark. The more luminous an object, the more intense is its effect upon the retina, just as two horns affect the ear more keenly than one. The more intense or stimulating a light, the quicker is the retina exhausted. It becomes temporarily paralyzed in the cones of such a color. Look at the sun, then look away, and you will still see the sun; but its color appears a pale blue, which is the farthest contrast to the yellow-orange of the sun. It is the complementary color. The light of the sun is so intense that it quickly exhausts the yellow-orange cones, leaving those farthest from it (blue, the "complementary" of yellow) least exhausted; hence this after-image of the sun looks blue (actually a pale greenish blue). "After-images" and purely subjective sensations of light and color often fool the judgment center of the mind that relies too implicitly upon the "visual center;" which partly accounts for many marvelous tales in human experiences. If we look long at a bright colored light, say red, the red-seeing cones will be so exhausted that when we look at other objects we shall see none of the red in them. We are temporarily red-blind.

A mother was sewing a scarlet gown held in the sunlight by the window. Turning to her child, playing upon the floor, she shrieked, believing it was dying. She saw no red in its face, which made it appear corpse-like. Visions, witch-making, religious hysteria, pseudo-insanity, and the attribution of supernatural power are intimately related to this unappreciated law of "after-images."

As pressure on the eyeball will cause the sensation of light, although the eye is closed, so will an over-active circulation of

blood in the "visual center" of the brain give the sensation of seeing. The visions of hysteria, delirium, and insanity are often the product of a disordered circulation in the visual center. They are the exaggeration of ordinary dreams, in which the blood sets the machinery of sight in motion, throwing a fanciful aurora upon the heavens of the imagination. Such disorders in a De Quincey set the unguided literary loom in motion. In a Jeanne d'Arc they led a confiding brain into a belief in a divine mission, into an innocent simulation of divinity that inspires a multitude to accomplish "miracles." In Figure IV the eye tells the brain that the line A—B is longer than C—D. It is an innocent lie, which the brain discovers by the use of a tape-line; but the eye holds to its falsehood.

The retina is a marvelous specialist. It can speak in only one language,—light,—but its vocabulary in this is greater than a hundred Shakesperes in the English tongue. Yet is it just as stupid at times as it is brilliant at others. If we press the eyeball in the dark, the retina will report to the brain that it sees a ring of light. If we stimulate it with an electric current, it will telegraph the brain, "Sudden appearance of a great light," which is an innocent lie. If we bump heads with a stranger in the dark, we may both "see stars."

Harmony in color, like harmony in music, may be defined as rates of two or more vibratory waves that enhance one another; and discords are the reverse. Thus, if two children are swinging in separate swings a few feet apart and in the same direction, they may be said to enhance each other's action when they swing up and down at the same time. If they do not, they will collide and break the rhythm. Two tuning-forks of discordant rates of vibration, set in action close together, will make no sound. It is possible that the harmonies of color waves may some day be reduced to mathematical tabulation.

Complementary colors, while representing the greatest contrasts, are harmonious; they work together in double-harness. Contrasts, properly used, produce a pleasing effect because they relieve tiring nerve fibrils and give exercise to others anxious to work. Do animals see color? A red flag excites the bull

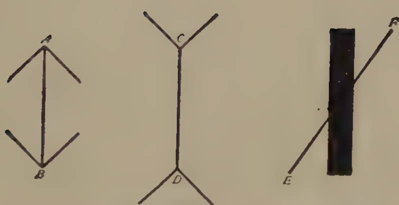

Fig. IV.—Diagrams showing that the Eyes may bear False Testimony to the Brain

The line A-B appears shorter than that from C to D, although of the same length. The line E-F appears bent as it passes through the black band, although straight

and awakens the curiosity of the antelope. A green or a blue flag of equal luminosity does not do so. Anglers know the value of color in the selection of "flies" in appealing to the whimsical appetites of the indifferent trout. Male birds consider their colored raiment of greater value than form and manners in courtship. Many animals take on the hue of their surroundings, and become less conspicuous to their enemies. The arctic fox is white, the Northern rabbit white in winter and brown in summer. The chameleon has in his skin a great number of little sacs filled with red, yellow, and black fluids, which he can expand at will, thus altering his appearance into red, orange, yellow, olive-green, and browns, according to the proportions of color-pots exposed. He must study the color of his surroundings, then decide how many sacs of red, yellow, etc., he must distend to match the shade. He does not always hit the shade at first, but he soon succeeds. Wonderful, is it not? And yet we see full-grown men expanding with velvet-gowned, long-haired egotism over their superiority as "colorists." Lubbock has shown that ants appreciate color. Probably the keenest color sense is possessed by birds. The proportion of cones is greater in them than in man.

Light and heat are the product of combustion, and are much the same thing. Artists call red, orange, and yellow warm colors, and green, blue, and violet cold. There is actually more heat in the waves of the warm trio than in the cold. Langley constructed a "bolometer" that will measure the heat in each color wave. Violet, blue, and blue-green rest the brain, while the other colors tend to irritate it. The latter over-stimulate, and soon act as a whip on the tired nerves. So in music, it takes a long time to weary of the violoncello, but a Scotch bagpipe is enjoyed longest when on the other side of the valley.

The waves of each color excite vibration in their own set of cones in the retina. Let us assume that each of the primary colors has its own set of cones. Various theories are held, one being that only red, green, and violet cones exist, the other colors being the product of mixtures of these three. Let us return to our pincushion simile, and to the fact that of the 7,000,000 cones,

500,000 are devoted to green, 600,000 to red, 700,000 to violet, 1,200,000 to blue, 1,800,000 to orange, and 2,200,000 to yellow. Then there are 130,000,000 rods which see white, or luminosity, the portion of light not absorbed by a color, but reflected. Let us assume that in an eye, in its making, the 500,000 cones which see green are left out. That eye would be color-blind to green. But it would still have its "rods" which would see the white light that is reflected as luminosity from all green objects, and would see this luminosity as so much gray. A totally color-blind eye would see only shades of gray from almost pure white to pure black. This is to some extent the way a photograph shows a landscape, and the gradations of light and shade are the degree of surface reflection of each color independent of its color waves. Yellow is very luminous, and shows comparatively white in the photograph. Violet is very slightly luminous, and appears very dark in the photograph. The eye that is color-blind in green, if it beheld a yellow-green, would see the yellow with the admixture of gray represented in the luminosity of the green, making a dirty yellow. Green would be shown in a photograph by a gray that is about half-way between black and white. If green-blind eyes looked at a slate roof of a shade resulting from the admixture of one portion of pure blue and one of pure green, they would see the product of admixture of one portion of pure blue and one half portion of medium gray, making a muddy blue—white, black, and blue. If red-blind eyes looked at a scarlet coat, they would see the yellow plus red's luminosity—a medium gray, producing a dirty yellow. But generally there is some sense of a color felt; not all the cones of a color are wanting. Then there will be a tinge of such color in the effect. The scarlet coat would show a little less gray and include some red, making a russet-brown. And in proportion to the brightness of its illumination would the sense of red be greater, just as those who are "hard of hearing" catch sounds that are emphasized.

To the totally color-blind all objects appear in grades of black and white, as in engravings, photographs, and black-and-white monotypes. This form is very rare. Where there is

total blindness in one or two colors, most of such cases are in red or green, or both.

There are many whose eyes can discriminate only the decided colors, neutral shades losing their distinction. Such eyes are at their best with the more luminous colors. They are to sight as the ears of the "hard of hearing" are to sound.

QUESTIONS AND EXERCISES

The value of concrete illustrations and familiar examples in expository writing has been emphasized in the study of many of the preceding selections, but the matter is so important that it is desirable to direct especial attention to it in this and the following selection. As Professor Lamont points out in his *Specimens of Exposition* "abstractions produce little or no effect until translated into concrete terms. If the writer himself does not translate them, the reader must; and this task makes hard reading." The danger of undue abstraction lies chiefly in the lazy contentment of the writer with somebody else's general terms. The remedy for this is to think a subject out in specific detail. Only when every general or abstract statement can be amplified by means of concrete particulars should there be assurance that the subject has been thought out thoroughly enough for your readers. The present selection illustrates a good deal of cleverness and resourcefulness in making a difficult and abstruse matter plain by illustrations and comparisons.

1. Is it true of the subject-matter, as the writer says, that it is the kind that makes "clearness and simplicity become somewhat difficult"? Compare in this regard with some of the selections previously studied.

2. Describe the method the writer has used. Note in this connection the first sentence of the second paragraph. Suggest another method by which the material might have been presented and determine whether the writer has used the easiest and simplest.

3. Study carefully the illustrations and comparisons used to make clear difficult ideas. Are these well selected for the purpose?

4. In what other way has the writer sought to give interest to his article?

5. Are his paragraphs uniformly of good construction?

Exercise 1. Write an explanation of one of the topics below, making especial effort at concreteness. The method of the foregoing selection

may be used—first an account of the process as it normally is, and then a brief explanation of the abnormal phase of it which you desire to explain—or any other method that seems suitable.

Deafness.
Aphasia.
Astigmatism.
Dyspepsia.
Diseases of the heart.
Stammering.

OF BOUNDARIES IN GENERAL [1]

William Kingdon Clifford

Before I begin to talk to you about the sizes and shapes of things, I am going to make a request that may seem somewhat strange. I am going to ask you to forget that you have ever lived until this moment. It is not that I am going to tell you anything new, that you did not know before; for I am merely going to remind you of a lot of things that you have known familiarly for years. Only I want you to observe them all quite freshly over again, as if you had not seen them before. I want you not to believe a word I say, unless you can see quite plainly at the moment that it is true; and I shall try only to say such things as you can quite easily verify at once while you sit there. That is what I mean by asking you to forget that you have ever lived until this moment: for geometry, you know, is the gate of science, and the gate is so low and small that one can only enter it as a little child.

Things take up *room*. Let us examine this fact rather closely. Here is a piece of wood which takes up room; that is to say, there is some room which is taken up by the wood, and some room which is not. Any *thing*, then, implies two rooms or spaces; one in which it is, and one in which it is not; one which

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it takes up or fills, and one which it does not fill; an *inside* space and an *outside* space. But it is not every two spaces that are so situated with regard to each other as these spaces are. Here, for instance, is a glass of water. The water also takes up room, and makes a difference between the space where there is water and the space where there is not water. We are now considering those spaces; that in which there is this piece of wood, that in which there is this water, and that in which there is neither. Now if you try to go from any part of the wood-space to any part of the water-space, you will find that it is impossible to do so without passing through space which is neither wood nor water. But you can go from any part of the space where this piece of wood is to any part of the space where this piece of wood is not without passing through anything but these two spaces; and that in as many ways as you like. If you are inside the wood, you can get to the outside air without going through anything but wood and air. This property of the two rooms or regions, the inside and the outside, which are distinguished by everything, is denoted by the word *adjacent*, which means *lying close up to*. To say that two regions or spaces are adjacent is the same thing as to say that you can get from one to the other without going through anything but those two regions; and that in as many ways as you like.

The observation, then, that we have made so far is this. Every thing divides all space into two adjacent regions, the *inside* and the *outside*. Here I have scarcely spoken quite correctly. The thing takes up one of the two regions, and does not take up the other; so it constitutes the difference between them: but that which *divides* the one region from the other is not the thing itself, but the *surface* of the thing. In the case of this water, for example, there is a certain region taken up by the water in the glass, and a certain region taken up by the air above it; and the surface of the water is what divides one of those regions from the other; it is the *boundary* between them, which marks them off. Now there are four things to be noticed about this surface. They are things quite obvious and easy to be noticed, things that you have all noticed before; but it is

important that we should state them explicitly, and agree that we have observed them. *First*, it is the *surface* of *both* of those regions into which space is divided by it. The upper surface of the water is also the lower surface of the air.

If you like to see this in a very striking way, all you have to do is to lift up the glass of water until you can see the image of something reflected in that air-surface. It is a surface of wonderful brilliancy, reflecting in certain cases all the light which falls upon it. Now I can see the image of a part of the teaspoon in the figure formed by the surface of the air. This very simple experiment will enable you more easily to realise this fact, that what you call the surface of the water, when you view it from the air-side, is precisely the same surface as that which you call the surface of the air when you view it from the water-side. And the same remark is true of all other cases. Looking at this piece of wood from the outside, we should talk about the surface of the wood; that is to say, the surface of the inside space. But if we imagine our point of view transferred to the inside, we should talk about that very same surface as the surface of the air, that is to say, the surface of the outside space. So that until our point of view has been changed, we are apt to have a partial and one-sided notion of a surface.

The *second* remark that we have to make about a surface is that it takes up absolutely *no* room at all. This is the same thing as saying (what we said before) that the two regions into which space is divided by the surface are *adjacent*, that where one ends the other begins, namely, at the surface of both of them. Between water and air, for instance, there is absolutely no room at all; there is only the surface common to these two things. So that a surface has not even any right to be called a thing, in the sense in which things take up room. Possibly some one thinks that the surface of this piece of wood is a thin film of wood which is just outside all over it. Well, then, that is just what it is *not*. Suppose that I dipped the wood into water, and made it wet, leaving a very thin film of water all over. Would that film be a surface? No; for it would take up room. The film would have two surfaces—one outside, between water

and air, and one inside, between water and wood; and there would be room between those two surfaces, namely, the room taken up by the water of which the film is composed; which, being a thing, must take up room, however little there is of it. And half way between those two surfaces there might be another, dividing water that was outside it from water that was inside it; and, again, between that and each of the others there might be two more, and so on, as many times as you like; and still between two of these, however close together, there would be water, a thing taking up room, with one surface on the outside of it and one surface on the inside. Is this sheet of paper a surface? No; it has a surface above and a surface below. And if you were to split—not the sheet of paper, for that would be impossible—but the sheet of space in which the paper is, into a million sheets, and to-morrow one of those again into a million sheets, and the next day one of those into a million sheets, and if you kept up that process for a million years, the inconceivably thin sheet that you would have at the end would still be room, with a surface above and a surface below; it would be no nearer to being itself a surface than when you began. You see it is quite easy to say that a surface takes up no room; but it is not so easy to realise the enormous gulf that is fixed between very little and none at all. And when Euclid tells you that a surface has length and breadth, but *no thickness*, he means exactly what we have just been observing.

The two other points that we have to notice are about the *motion* of a thing. If I move this piece of wood about, I also move the surface of the wood. We must therefore regard a surface as capable of being moved about. Now there is a property of every motion that takes place, which is also a property of this motion of a surface; a property which is, no doubt, implied in our ordinary use of the word *move*, but which is not always sufficiently prominent in it. This motion is *continuous*. Now the idea expressed by that word *continuous* is one of extreme importance; it is the foundation of all exact science of things; and yet it is so very simple and elementary, that it must have been almost the first clear idea that we got into our heads.

It is only this: I cannot move this thing from one position to another, without making it go through an infinite number of intermediate positions. *Infinite;* it is a dreadful word, I know, until you find out that you are familiar with the thing which it expresses. In this place it means that between any two positions there is some intermediate position; between that and either of the others, again, there is some other intermediate; and so on *without any end.* Infinite means without any end. If you went on with that work of counting for ever, you would never get any further than the beginning of it. At last you would only have two positions very close together, but not the same; and the whole process might be gone over again, beginning with those as many times as you like.

But, you will say, what is the use of telling me that motion is continuous, when I cannot conceive of it as being anything else? Then I will try to tell you what discontinuous motion would be like. If this piece of wood were to be annihilated as soon as it got here, and then to come into being again over there, so as to have got from one position to the other without passing through any intermediate positions, its motion would be discontinuous. It would go by a jump from one place to another; and continuous means *holding together* all through, without any jumps. But this would not be *moving*, you will say; and besides, the state of things is impossible. Very well; I said (if you recollect) that the idea of continuity was implied in the word move, and that it was so exceedingly simple and elementary that it must have been almost the first clear idea that got into our heads. It is no wonder, then, that it should be firmly lodged there now. At another time we may be able to see some of the consequences of this idea. At present we have only to remember our third observation about surfaces; that any surface may be moved continuously from one position to another.

Now a surface, you will remember, is that which separates two different regions of space; the difference between them being that something is in one and is not in the other. But two regions of space may differ in this way: that, five minutes ago, a thing *was* in one of them and was not in the other. These

two regions are still adjacent, still separated by a surface. So that although a thing is moved away and its surface is moved away with it, yet it is also true that the surface remains in the same place. It is no longer the surface of the thing, but it is the surface of those two regions which *were* marked out by the thing. The two regions, of course, are always there, and from having been different once they are distinct for ever. Thus when anything is moved you see that there must be an infinite number of surfaces, each of which has at some instant or other been the surface of the thing. Now here there are two cases to be distinguished. Consider the surface of this water; when I agitate it the water moves about, and the surface continually changes. All this time the water has been changing its shape, and at any one instant it would not fit the surface which it had at any other instant. But if I move this piece of wood, which does not change either in size or shape, the surfaces which it has at different times are such that any one of them would fit the wood at any time; they are all exactly of the same shape, and all exactly of the same size. This being so, the regions of space which are filled by the wood at two different times are called *congruent* regions. Two regions of space are congruent when a thing which exactly fills one of them can be made exactly to fill the other by moving it, without changing its size or shape. Or we may express the same thing by saying that the surface of the two regions can be put together so as to fit each other all over.

Let us now put together the observations that we have made so far. Only instead of the word *thing*, which I have used hitherto, I want to use the word *body*, which is rather more accurate. A body is anything that takes up room. This piece of wood is a body; the water in the glass is a body; the air all about is a body. We have observed, then, that every body discriminates two adjacent regions of space; that the surface of the body divides these two regions from one another; it is surface to both of them equally; it takes up no room; it can be moved continuously with the body, and yet it remains when the body is taken away. We have also given a name to those re-

gions which are of the same shape and size: we have called them congruent regions.

Now if you will look at the surface of this sheet of paper you will observe that a part of it is coloured red. That red patch takes up room on the surface; but this is surface-room that is taken up, a different kind of room from that which is taken up by a solid body. The red colour distinguishes between two regions of the surface, precisely as a body distinguishes between two regions of solid space. And the two surface-regions are adjacent; that is to say, you can get from red to white on the surface without going over any part of the surface except red and white; exactly where the red ends the white begins. That which divides one of these surface-regions from the other is the boundary-*line* of both of them. This line is neither white nor red; it takes up no room whatever on the surface. If with a very fine pen I try to draw a line on the surface, what shall I in fact have done? I shall have made a portion of the surface black, and the boundary of the black portion is a line. It is certainly a long narrow portion that I have made black, so that we may say it has a line on one side, and a line on the other side. Between those two lines there is an infinite number of other lines. No matter how microscopically fine was the mark that you made, it would always be a portion of the surface that you had made black, a region taking up surface room. There would always be a line on one side and a line on the other side, separating black from white, and between these two there would always be an infinite number of lines.

Moreover, if I move this sheet of paper about, I shall move about all the lines that are on its surface. And yet the lines will remain where they were. For there is a distinction between the space where at any instant paper was and the space where paper was not; and of the surface that parts those two spaces there is a distinction between that which was surface of red paper and that which was surface of white paper. The boundary between these two surface-regions is a line, still existing, because the distinction between those two surface regions still exists. A line may even move upon a surface while the surface

remains still. If, for instance, we cast a shadow on the paper, then the boundary of light and shade is a line; and when we make the shadow move about the line moves about too, though it still remains to mark the distinction between what was shadow and what was not shadow.

Thus, you see, all the remarks that we made about regions of solid room and their boundaries have their counterparts when we come to speak about regions of surface-room and their boundaries. But there is one more remark to be made here, which is not similar to any that we have made before. And that is, that a line may be regarded from two entirely distinct points of view.

One of these we have already considered. We have already looked upon a line as the boundary between two adjacent regions of surface, and we have noticed the analogy between this idea of a line and the idea which we have previously formed of a surface as the boundary between two adjacent regions of solid space. But now, suppose that I dip a part of this piece of paper into water; and please to imagine that the surface of the water goes on through the paper to the other side, and is not stopped by it. Then there is a line upon the surface of the paper, viz. the line which divides paper-surface which is in water from paper-surface which is out of water; and there is also a line upon the surface of the water, viz. the line which divides the water-surface on one side of the surface of paper from the water-surface on the other side. And these two lines are exactly the same line; a single line lying both on the paper-surface and also on the water-surface. Moreover, if you were asked, "Where do those surfaces meet?" you would answer, "They meet in that line which is common to them both." It is just at that line that each surface *intersects* the other, or *cuts between* two portions of it, which are thereby separated. So that the line is to be considered as existing in space, quite independently of the particular surface which it divides into two portions. It might be possible to agitate the water or move about the piece of paper so as to leave the line quite still, and in that case there would be an infinite number of surfaces all passing through the

line. Now when I say that the line exists independently of the particular surface which it divides, I do not mean that you can get at the idea of a line without thinking of a surface which it divides, but that there is no reason why out of that infinite number of surfaces you should choose any one in particular. You must have *a* surface, but you are not bound to any *one*.

A line, then, is not only the boundary between two adjacent regions of a surface, but also it is the *intersection* of two surfaces.

Let us return to the contemplation of the red patch on the surface of this paper. Especially consider the line which bounds it. I will throw a shadow on part of the line. Now the shadow takes up line-room; there is a part of the line which is in shadow, and a part of the line which is not in shadow. That which divides one of these parts from the other is the *point* which is the boundary of both; which marks where one of them ends and the other begins. The point takes up no room of any kind whatever, not even line-room, the last kind that we have considered. Here, then, we have come to something quite different from the other two boundaries that we talked about. A body takes up more or less space; it is quite intelligible to ask how much space it fills. So a patch may take up more or less surface, and you may say, "How much line does the shadow cover?" But if you said, "How much point?" you would be talking nonsense; that is to say, you would be putting words together when the ideas that correspond to them will not go together. The idea of *how much* is utterly foreign to the idea of *point*. Point cannot be measured; there are no parts of it to be distinguished from one another. Here we are at the first word of Euclid: a point is that which has no parts, or which has no magnitude. Only we are much richer than any one who begins at that first word, for we are making a statement which we see to be true about something which we know independently of that statement, and which, moreover, we can look at in four different lights. A point, namely, is not only a boundary, and so may have made about it the remarks that we have made about other boundaries, but it is an intersection, and that in

three several ways. First, it is the intersection of two lines on a surface; for instance, of this boundary of red crossed by the boundary of shadow. There is a point on the first line, dividing light from shade, and a point on the second line dividing red from white; and these two are the same point, common to the two lines. At this point the two lines meet, and each intersects the other, or cuts between two parts of it which are thereby separated. Next, it is the intersection of a line and a surface, dividing that part of the line which is on one side of the surface from that part of the line which is on the other side; as when I dip a piece of paper which is half red into water, there is a point dividing that part of the red boundary which is in water from that part which is out of it. And lastly, a point is the intersection of three surfaces, a remark which you will find easy to illustrate, *e. g.* by the corner of a room, which is the intersection of the surfaces of the two walls and of the floor.

We have now considered in succession four different ideas: solid space or volume, surface, line, point, and we have regarded each of them as the boundary between two adjacent regions of the preceding. It remains for us to go straight back again over the same route, to consider in succession point, line, surface, volume, regarding each as the *path* of the preceding. For when a point moves, it moves along some line; and you may say that it traces out or describes the line. To look at something definite, let us take the point where this boundary of red on paper is cut by the surface of water. I move all about together. Now you know that between any two positions of the point there is an infinite number of intermediate positions. Where are they all? Why, clearly, in the line along which the point moved. That line is the place where all such points are to be found. But because this statement, so made, is quite simple and sensible and easy to be understood, we must needs translate it into Latin, and say, "The line is the *locus* of the successive positions of a moving point." Locus means merely place, both naturally and technically. There is no meaning whatever in the statement "That line is the locus of the successive positions of a moving point" which is not fully and entirely conveyed by this

other statement of the same thing: The line is the place where all those successive positions are.

I have laid some stress on this, because it seems to be a fair opportunity for warning you of a very serious danger: the danger of thinking that there is any mystery in a technical term. So long as you use it merely to save time and trouble, as an abbreviation, namely, for other simple words or phrases which everybody can understand, a technical word will be useful and harmless. But directly you begin to think that there is some hidden and mysterious meaning in it, which cannot be expressed in simple ordinary words that everybody could understand, there is no end to the nonsense that it will help you to think and talk. And when I have been using technical words, and am not not quite sure whether I have been talking nonsense or no, I have one very safe way of finding out. I translate the whole thing into English, that is to say, into short easy words of Saxon origin. For there is an amazing amount of mystery in Latin and Greek terminations; and so long as any of these are left, I am never quite certain that I know what I mean.

Then you must not imagine that the Latin word *locus*, as used in geometry, means anything more or less than the English word place. When a point moves along a line, that line is the *locus* of the successive positions of the moving point, or the *place* where they all are.

In an exactly similar way, if a line moves about, it traces out a surface, which is called its path. Between any two positions of the line, there is an infinite number of intermediate positions; and the surface is the place where all these are, or the locus of the successive positions of the moving line. Lastly, by the motion of a surface a solid space or volume is traced out; and this volume may be called the path of the surface or the locus of its successive positions. Thus we have three kinds of *room*, solid-room, surface-room, and line-room; and three several *boundaries* to them, surface, line, and point; four *intersections*, surface with surface, surface with line, line with line, and three surfaces together; and three *paths* whereby a boundary, moving, may trace out that of which it is a boundary;

namely, a solid is the path of a surface, a surface of a line, and a line of a point.

But we have not quite done with this last idea. We have first to make ourselves secure against a possible mistake about it, and then to observe some very important consequences that flow from it.

It seems a very natural thing to say that space is made up of points. I want you to examine very carefully what this means, and how far it is true. And let us first take the simplest case, and consider whether we may safely say that a line is made up of points. If you think of a very large number—say, a million—of points all in a row, the end ones being an inch apart; then this string of points is altogether a different thing from a line an inch long. For if you single out two points which are next one another, then there is no point of the series between them; but if you take two points on a line, however close together they may be, there is an infinite number of points between them. The two things are different *in kind*, not in degree. The failure to make a line does not mean that you have not taken a large enough number, but that *number itself* is essentially inadequate to make points into a line. However large a number you imagined, we might divide an inch into that number of parts, and each of these parts would be a little piece of line-room with a point at each end of it, and an infinite number of points between them. So that if, when you said, "A line can be made up of points," you meant this: "If I count a large enough number, and take that number of points, and lay them in a row, then I shall make a line," it would not be true. It is not at all true that a line can be made up of points in that way. Nor is it any more true in that sense that a surface can be made up of lines, or a solid of surfaces. If you took millions and millions of lines and laid them side by side, you would have something which is not a surface at all, but an entirely different thing, viz. a large number of lines. Between two of those lines there would be nothing belonging to the series of lines; but between two lines on a surface, however close together they are, there is always a little strip of surface-room, in which an infinite

number of lines can be drawn on the surface. And so if you took any number of surfaces, it would be utterly impossible to make a solid with them. Two of your surfaces must either be distinct, in which case there would be solid room between them; or they must coincide, in which case they would take up no more room than one surface, that is to say, absolutely none at all. So far, then, it would appear that we must answer *no* to the question "Is space made up of points?"

In fact, when we said that there is an infinite number of points in a piece of line-room, we might have said a great deal more. Suppose, for instance, that anyone said, "How many miles is it possible to go up into space?" the answer would of course be, "An infinite number of miles." (Don't be frightened at this continual occurrence of the word infinite: it still means "without any end," and nothing more.) In this case, if you go a mile and count one, then another and count two, and so on, all we mean is that the process would never end. There would still be space left to go up into, however many millions of miles you had counted. But still all those miles would be counted and done with. Your task would have been distinctly begun, and there would be nothing more to say to the miles behind you. But try now to count the points in a piece of line. You count one, two, three, four, a million points; and your task is not even begun. The line is all there, exactly as it was before; absolutely none of it is done with. The million points take up no more line-room than one point; that is to say, absolutely none at all. When then we are talking of the points in a piece of line, we must say not merely that there is a never-ending number of them (which there is), but that they are out of the reach of number altogether. All the points in a line are not, properly speaking, a number of points at all. If we are going to speak about the *number* of points in a line, we must settle beforehand that we are going to use the word in a new sense, which is not derived from counting, but from this very observation to which we have applied it.

Let us now make use of our idea of a path. When a point moves along a line, we know that between any two positions

of it there is an infinite number (in this new sense) of intermediate positions. That is because the motion is continuous. Each of those positions is where the point was at some instant or other. Between the two end positions on the line, the point where the motion began and the point where it stopped, there is no point of the line which does not belong to that series. We have thus an infinite series of successive positions of a continuously moving point, and in that series are included all the points of a certain piece of line-room. May we say then that the line is made up of that infinite series of points?

Yes; if we mean no more than that the series makes up the *points* of the line. But *no*, if we mean that the line is made up of those points in the same way that it is made up of a great many very small pieces of line. A point is not to be regarded as a *part* of a line, in any sense whatever. It is the boundary between two parts. The parts of a piece of solid room are smaller pieces of solid room, and not surfaces. The parts of a piece of surface are smaller pieces of surface, and not lines. The parts of a piece of line are smaller pieces of line, and not points. So you must be very careful to remember that a line is a different thing from the aggregate of all the points upon it; the points are on the line, but they are not the line itself. And the same distinction must be kept between a surface and all the positions of a line which traces it out; the surface is the place where all the lines are, but it is not the lines themselves. Finally, there are innumerable points and lines and surfaces in solid space; but space itself is essentially a different thing from all of them, which can be traced out by their continuous motion, but cannot be built up by putting them together.

On the whole, then, we must answer *no* to the question that we have discussed. To say that space is made up of points would be to say that space is the same thing as all the points in it, which is certainly untrue. And we may now, I think, without fear of mistake, use the word number in that extended sense which we proposed to give to it. We said, you remember, that in speaking of the number of points in a line, we must mean

a great deal more than when we speak of the number of miles that you can go before coming to the end of space. For this last number is a number of *parts*. Every mile is a part of the whole distance; an immeasurably small part, of course, but still a distance, a thing of the same kind as the whole distance. But the other number is not a number of parts; it is a number of points which trace out a line not by *repetition* of themselves, but by *continuous motion*. And the idea which you have to attach to the word number is not to be got from elsewhere, but from the contemplation of this fact itself. I can recommend it as a very fruitful subject of contemplation, which has led people to the most important discoveries.

The number of points on a piece of line is *singly infinite*. You understand all this now, excepting the word *singly*. And that is what I am going to explain. Let us consider what is the number of points on a piece of surface. It is at least infinite, for if you draw any line on the surface, all the points on that line must be reckoned, and there is an infinite number of them. But it is more than that. For when you have traced out a line by the continuous motion of a point, you can trace out the surface by the continuous motion of that line; so that first you have an infinite number of points on the line, and then an infinite number of these infinities. Thus you see that the number of points on a piece of surface is twice as infinite as the number of points on a piece of line; or, as we are accustomed to say, the former is *doubly infinite*, and the latter *singly infinite*. Let us next consider what is the number of points in a piece of solid space. First you trace out a line by the continuous motion of a point; that gives you a *singly* infinite number of points. Then you trace out a surface by the continuous motion of that line. This gives you a singly infinite number of such lines, and a *doubly* infinite number of points. Lastly, you trace out the solid by the continuous motion of the surface. The number of surfaces is then *singly infinite*. Of lines, there is an infinite number of such infinities; that is, the number of lines is *doubly infinite*. Of points, there is an infinite number of double infinities; so that the number of points in a piece of solid space is

three times as infinite as the number of points in a line. This number is called *triply infinite*.

In how many directions can I look without moving my head? If I put myself in front of a wall, every point on the surface of the wall is in a definite direction from my eye, and every direction leads to a definite point on the wall. Thus there are just as many directions as there are points on that surface; that is to say, a doubly infinite number of directions.

How many pairs of points are there on a piece of line? Let the first point move along the line; it will have a singly infinite number of positions. Select one of these, and then let the second point move along the line. It will have an infinite number of positions for each position of the other; thus altogether there will be a doubly infinite number of pairs. In the same way you will find that there is a triply infinite number of sets of three points, or of triads of points, on a piece of line.

All these things can be said in another way. Suppose that all you knew about a point was that it was on a certain line. That would not enable you to identify the point; for you would not know which it was out of a singly infinite number. The point might vary among all the points on the line, and still fulfil the condition of being a point on the line. Still it could only vary in that one way. Such a point is said to have one variation. It is able to move about, but only on a fixed line. But to tell you that the point is on a certain surface would be to tell you less than this, for you would have a doubly infinite number of points to choose from. Suppose the surface traced out by the motion of a line; then the point might lie on any position of the line, and anywhere on the line. It could move along the line, and then the line might move along the surface. Such a point is said to have *two* variations. If now you are told merely that the point is in a certain region of solid space, you have a triply infinite number of points to choose from, and the point is said to have three variations. It may move along a line, then the line may move on a surface, and then the surface may move in space. Now the three kinds of room are distinguished by the number of dimensions that they have. Solid

room has three dimensions, length, breadth, and thickness. Surface room has length and breadth, but no thickness. Line room has no breadth or thickness, but only length. So we may now say that a point in space of three dimensions (solid room) has three variations; a point in space of two dimensions (surface room) has two variations; and a point in space of one dimension (line room) has one variation.

You must not suppose, however, that the idea of a number of variations is confined to single points. A pair of points on a line has two variations, for the two points may move independently. A direction in which you can look has two variations; for it may take up a doubly infinite number of positions. And by-and-by we shall be able to see that a space has four variations—three of position and one of size. In order to identify a thing you must be told as many facts about it as it has variations. Thus a point on a line is identified if you know one fact about it, say the distance from one end of the line. But to identify a point on the earth's surface you must know two things; for instance, the latitude and the longitude. And to identify a point in space you must know three things—the latitude, the longitude, and the height.

I dare say, now, that you are rather indignant at being kept so long hearing perfectly obvious remarks that are true of everything. You may think it is beneath the dignity of human nature to spend all this time in contemplating the size and shape of a piece of wood. Very well; it is written in the fifteenth chapter of the Koran that when Adam was created all the angels were commanded to worship him. But Eblis, the chief of them, refused, saying, "Far be it from me that am a pure spirit to worship a creature of clay." And for this refusal he was shut out for ever from Paradise. Now the doom of Eblis awaits you if you fail to give due reverence to these little obvious everyday things—things that are true of every stone that lies on the pavement, of every drop of rain that falls from heaven, of every breath of air that fans you. Like him, you will find with astonishment that the creature of clay which you despise is the Lord of Nature and the Measure of all things, for in every speck

of dust that falls lie hid the laws of the universe; and there is not an hour that passes in which you do not hold the Infinite in your hand.

QUESTIONS AND EXERCISES

The material of this selection -geometric concepts—is highly abstract. The writer's extraordinary acuteness and originality, however, enabled him to make his subject clear by great cleverness and resourcefulness of illustration. The style of the piece shows evidently that it was originally a lecture to a popular audience, and was composed primarily not for reading but for hearing.

1. In the first paragraph Clifford says, "I want you not to believe a word I say, unless you can see quite plainly at the moment it is true," etc. Do the illustrations and other devices for making the abstract clear seem to show that the writer has great powers of concrete visualization? Is he trying to get his readers to visualize what he is explaining to them? Is there an hint for the expository writer in the old saying, "Seeing is believing"?

2. Tabulate the main headings of this selection. Has the writer discussed completely enough the subject?

3. Do you notice much repetition of ideas—frequently in the same forms of expression? Does this have value in a lecture of the sort this selection was originally?

4. Is Clifford's choice of words adapted to his readers? Do you think his warning about the danger in the use of technical terms worth heeding? In his vocabulary, which predominate—words of Saxon origin or words of Latin and Greek derivation? Is he possibly practising what he preaches on page 378?

Exercise 1. By means of the clearest and most vivid analogies and comparisons you can think of, make clear to an audience of workingmen one of the following. Endeavor to make your readers "see" what you are explaining.

The nervous system in man.
Light wave motion.
The action of the lungs.

SIMPLIFYING A MASS OF MATERIAL

THE RHYTHM OF MOTION[1]

HERBERT SPENCER

WHEN the pennant of a vessel lying becalmed first shows the coming breeze, it does so by gentle undulations that travel from its fixed to its free end. Presently the sails begin to flap; and their blows against the mast increase in rapidity as the breeze rises. Even when, being fully bellied out, they are in great part steadied by the strain of the yards and cordage, their free edges tremble with each stronger gust. And should there come a gale, the jar that is felt on laying hold of the shrouds shows that the rigging vibrates while the rush and whistle of the wind prove that in it, also, rapid undulations are generated. Ashore the conflict between the current of air and the things it meets results in a like rhythmical action. The leaves all shiver in the blast; each branch oscillates; and every exposed tree sways to and fro. The blades of grass and dried bents in the meadows, and still better the stalks in the neighboring corn fields, exhibit the same rising and falling movement. Nor do the more stable objects fail to do the like, though in a less manifest fashion; as witness the shudder that may be felt throughout a house during the paroxysms of a violent storm. Streams of water produce in opposing objects the same general effects as do streams of air. Submerged weeds growing in the middle of a brook undulate from end to end. Branches brought down by the last flood, and left entangled at the bottom where the current is rapid, are thrown into a state of up and down move-

[1] Reprinted from *First Principles*, by permission of Messrs. D. Appleton & Co.

ment that is slow or quick in proportion as they are large or small; and where, as in great rivers like the Mississippi, whole trees are thus held, the name "sawyers," by which they are locally known, sufficiently describes the rhythm produced in them. Note again the effect of the antagonism between the current and its channel. In shallow places, where the action of the bottom on the water flowing over it is visible, we see a ripple produced—a series of undulations. And if we study the action and reaction going on between the moving fluid and its banks, we still find the principle illustrated, though in a different way. For in every rivulet, as in the mapped-out course of every great river, the bends of the stream from side to side throughout its tortuous course constitute a lateral undulation—an undulation so inevitable that even an artificially straightened channel is eventually changed into a serpentine one. Analogous phenomena may be observed where the water is stationary and the solid matter moving. A stick drawn laterally through the water with much force, proves by the throb which it communicates to the hand that it is in a state of vibration. Even where the moving body is massive, it only requires that great force should be applied to get a sensible effect of like kind: instance the screw of a screw steamer, which instead of a smooth rotation falls into a rapid rhythm that sends a tremor through the whole vessel. The sound which results when a bow is drawn over a violin-string, shows us the vibrations produced by the movement of a solid over a solid. In lathes and planing machines, the attempt to take off a thick shaving causes a violent jar of the whole apparatus, and the production of a series of waves on the iron or wood that is cut. Every boy in scraping his slate pencil finds it scarcely possible to help making a ridged surface. If you roll a ball along the ground or over the ice, there is always more or less up and down movement—a movement that is visible while the velocity is considerable, but becomes too small and rapid to be seen by the unaided eye as the velocity diminishes. However smooth the rails, and however perfectly built the carriages, a railway train inevitably gets into oscillations, both lateral and vertical. Even where moving matter

is suddenly arrested by collision, the law is still illustrated; for both the body striking and the body struck are made to tremble; and trembling is rhythmical movement. Little as we habitually observe it, it is yet certain that the impulses our actions impress from moment to moment on surrounding objects, are propagated through them in vibrations. It needs but to look through a telescope of high power, to be convinced that each pulsation of the heart gives a jar to the whole room. If we pass to motions of another order—those namely which take place in the ethereal medium—we still find the same thing. Every fresh discovery confirms the hypothesis that light consists of undulations. The rays of heat, too, are now found to have a like fundamental nature: their undulations differing from those of light only in their comparative lengths. Nor do the movements of electricity fail to furnish us with an illustration; though one of a different order. The northern aurora may often be observed to pulsate with waves of greater brightness; and the electric discharge through a vacuum shows us by its stratified appearance that the current is not uniform, but comes in gushes of greater and lesser intensity. Should it be said that at any rate there are some motions as those of projectiles, which are not rhythmical, the reply is, that the exception is apparent only; and that these motions would be rhythmical if they were not interrupted. It is common to assert that the trajectory of a cannon ball is a parabola; and it is true that (omitting atmospheric resistance) the curve described differs so slightly from a parabola that it may practically be regarded as one. But, strictly speaking, it is a portion of an extremely eccentric ellipse, having the Earth's center of gravity for its remoter focus; and but for its arrest by the substance of the Earth, the cannon ball would travel round that focus and return to the point where it started; again to repeat this slow rhythm. Indeed, while seeming at first sight to do the reverse, the discharge of a cannon furnishes one of the best illustrations of the principle enunciated. The explosion produces violent undulations in the surrounding air. The whiz of the shot, as it flies towards its mark, is due to another series of atmospheric undulations.

And the movement to and from the Earth's center, which the cannon ball is beginning to perform, being checked by solid matter, is transformed into a rhythm of another order; namely, the vibration which the blow sends through neighboring bodies.

Rhythm is very generally not simple but compound. There are usually at work various forces, causing undulations differing in rapidity; and hence it continually happens that besides the primary rhythms there are secondary rhythms, produced by the periodic coincidence and antagonism of the primary ones. Double, triple, and even quadruple rhythms, are thus generated. One of the simplest instances is afforded by what in acoustics are known as "beats": recurring intervals of sound and silence which are perceived when two notes of nearly the same pitch are struck together, and which are due to the alternate correspondence and antagonism of the atmospheric waves. In like manner the various phenomena due to what is called interference of light severally result from the periodic agreement and disagreement of ethereal undulations—undulations which, by alternately intensifying and neutralizing each other, produce intervals of increased and diminished light. On the sea-shore may be noted sundry instances of compound rhythm. We have that of the tides, in which the daily rise and fall undergoes a fortnightly increase and decrease, due to the alternate coincidence and antagonism of the solar and lunar attractions. We have again that which is perpetually furnished by the surface of the sea; every large wave bearing smaller ones on its sides, and these still smaller ones; with the result that each flake of foam, along with the portion of the water bearing it, undergoes minor ascents and descents of several orders while it is being raised and lowered by the greater billows. A quite different and very interesting example of compound rhythm, occurs in the little rills which, at low tide, run over the sand out of the shingle banks above. Where the channel of one of these is narrow, and the stream runs strongly, the sand at the bottom is raised into a series of ridges corresponding to the ripple of the water. On watching for a short time, it will be seen that these ridges are being raised higher and the ripple growing stronger; until at length, the

action becoming violent, the whole series of ridges is suddenly swept away, the stream runs smoothly, and the process commences afresh. Instances of still more complex rhythms might be added; but they will come more appropriately in connexion with the several kinds of cosmical changes, hereafter to be dealt with.

From the ensemble of the facts as above set forth, it will be seen that rhythm results wherever there is a conflict of forces not in equilibrium. If the antagonist forces at any point are balanced, there is rest; and in the absence of motion there can of course be no rhythm. But if instead of a balance there is an excess of force in one direction—if, as necessarily follows, motion is set up in that direction; then for that motion to continue uniformly in that direction, it is requisite that the moving matter should, notwithstanding its unceasing change of place, present unchanging relations to the sources of force by which its motion is produced and opposed. This, however, is impossible. Every further transfer through space must alter the ratio between the forces concerned—must increase or decrease the predominance of one force over the other—must prevent uniformity of movement. And if the movement cannot be uniform, then, in the absence of acceleration or retardation continued through infinite time and space (results which cannot be conceived) the only alternative is rhythm.

A secondary conclusion must not be omitted. In the last chapter we saw that motion is never absolutely rectilinear; and here it remains to be added that, as a consequence, rhythm is necessarily incomplete. A truly rectilinear rhythm can arise only when the opposing forces are in exactly the same line; and the probabilities against this are infinitely great. To generate a perfectly circular rhythm the two forces concerned must be exactly at right angles to each other, and must likewise have a certain ratio; and against this the probabilities are likewise infinitely great. All other proportions and directions of the two forces will produce an ellipse of greater or less eccentricity. And when, as indeed always happens, above two forces are engaged, the curve described must be more complex;

and cannot exactly repeat itself. So that in fact throughout nature, this action and reaction of forces never brings about a complete return to a previous state. Where the movement is much involved, and especially where it is that of some aggregate whose units are partially independent, anything like a regular curve is no longer traceable; we see nothing more than a general oscillation. And on the completion of any periodic movement, the degree in which the state arrived at differs from the state departed from, is usually marked in proportion as the influences at work are numerous.

That spiral arrangement so general among the more diffusing nebulæ—an arrangement which must be assumed by matter moving towards a center of gravity through a resisting medium—shows us the progressive establishment of revolution, and therefore of rhythm, in those remote spaces which the nebulæ occupy. Double stars, moving around common centers of gravity in periods some of which are now ascertained, exhibit settled rhythmical actions in distant parts of our sidereal system. And another fact which, though of a different order, has a like general significance, is furnished by variable stars—stars which alternately brighten and fade.

The periodicities of the planets, satellites, and comets are so familiar that it would be inexcusable to name them, were it not needful here to point out that they are so many grand illustrations of this general law of movement. But besides the revolutions of these bodies in their orbits (all more or less eccentric) and their rotations on their axes, the Solar System presents us with various rhythms of a less manifest and more complex kind. In each planet and satellite there is the revolution of the nodes—a slow change in the position of the orbit-plane, which after completing itself commences afresh. There is the gradual alteration in the length of the axis major of the orbit; and also of its eccentricity: both of which are rhythmical alike in the sense that they alternate between maxima and minima, and in the sense that the progress from one extreme to the other is not uniform, but is made with fluctuating velocity. Then, too, there is the revolution of the line of apsides, which in course

of time moves round the heavens—not regularly, but through complex oscillations. And further, we have variations in the directions of the planetary axes—that known as nutation, and that larger gyration which, in the case of the Earth, causes the procession of the equinoxes. These rhythms, already more or less compound, are compounded with each other. Such an instance as the secular acceleration and retardation of the moon, consequent on the varying eccentricity of the Earth's orbit is one of the simplest. Another, having more important consequences, results from the changing direction of the axes of rotation in planets whose orbits are decidedly eccentric. Every planet, during a certain long period, presents more of its northern than of its southern hemisphere to the sun at the time of its nearest approach to him; and then, again, during a like period, presents more of its southern hemisphere than of its northern—a recurring coincidence which, though causing in some planets no sensible alteration of climate, involves in the case of the Earth an epoch of 21,000 years, during which each hemisphere goes through a cycle of temperate seasons, and seasons that are extreme in their heat and cold. Nor is this all. There is even a variation of this variation. For the summers and winters of the whole Earth become more or less strongly contrasted, as the eccentricity of its orbit increases and decreases. Hence during increase of the eccentricity, the epochs of moderately contrasted seasons and epochs of strongly contrasted seasons, through which alternately each hemisphere passes, must grow more and more different in the degrees of their contrasts; and contrariwise during decrease of the eccentricity. So that in the quantity of light and heat which any portion of the Earth receives from the sun, there goes on a quadruple rhythm: that of day and night; that of summer and winter; that due to the changing position of the axis at perihelion and aphelion, taking 21,000 years to complete; and that involved by the variation of the orbit's eccentricity, gone through in millions of years.

Those terrestrial processes whose dependence on the solar heat is direct, of course exhibit a rhythm that corresponds to the periodically changing amount of heat which each part of the

Earth receives. The simplest, though the least obtrusive, instance is supplied by the magnetic variations. In these there is a diurnal increase and decrease, an annual increase and decrease, and a decennial increase and decrease; the latter answering to a period during which the solar spots become alternately abundant and scarce: beside which known variations there are probably others corresponding with the astronomical cycles just described. More obvious examples are furnished by the movements of the ocean and the atmosphere. Marine currents from the equator to the poles above, and from the poles to the equator beneath, show us an unceasing backward and forward motion throughout this vast mass of water—a motion varying in amount according to the seasons, and compounded with smaller like motions of local origin. The similarly caused general currents in the air have similar annual variations similarly modified. Irregular as they are in detail, we still see in the monsoons and other tropical atmosphere disturbances, or even in our own equinòctial gales and spring east winds, a periodicity sufficiently decided. Again, we have an alternation of times during which evaporation predominates: shown in the tropics by strongly marked rainy seasons and seasons of drought, and in the temperate zones by corresponding changes of which the periodicity, though less definite is still traceable. The diffusion and precipitation of water, besides the slow alternations answering to different parts of the year, furnish us with examples of rhythm of a more rapid kind. During wet weather, lasting, let us say, over some weeks, the tendency to condense, though greater than the tendency to evaporate, does not show itself in continuous rain; but the period is made up of rainy days and days that are wholly or partially fair. Nor is it in this rude alternation only that the law is manifested. During any day throughout this wet weather a minor rhythm is traceable; and especially so when the tendencies to evaporate and to condense are nearly balanced. Among mountains this minor rhythm and its causes may be studied to great advantage. Moist winds, which do not precipitate their contained water in passing over the comparatively warm lowlands, lose so much heat when

they reach to cold mountain-peaks, that condensation rapidly takes place. Water, however, in passing from the gaseous to the fluid state, gives out a considerable amount of heat; and hence the resulting clouds are warmer than the air that precipitates them, and much warmer than the high rocky surfaces round which they fold themselves. Hence in the course of the storm, these high rocky surfaces are raised in temperature, partly by radiation from the enwrapping cloud, partly by contact of the falling raindrops. Giving off more heat than before, they no longer lower so greatly the temperature of the air passing over them; and so cease to precipitate its contained water. The clouds break; the sky begins to clear; and a gleam of sunshine promises that the day is going to be fine. But the small supply of heat which the cold mountain's sides have received, is soon lost: especially when the dispersion of the clouds permits free radiation into space. Very soon, therefore, these elevated surfaces, becoming as cold as at first (or perhaps even colder in virtue of the evaporation set up) begin again to condense the vapour in the air above; and there comes another storm, followed by the same effects as before. In lowland regions this action and reaction is usually less conspicuous, because the contrast of temperature is less marked. Even here, however, it may be traced; and that not only on showery days, but on days of continuous rain; for in these we do not see uniformity: always there are fits of harder and gentler rain that are probably caused as above explained.

Of course these meteorologic rhythms involve something corresponding to them in the changes wrought by wind and water on the Earth's surface. Variations in the quantity of sediment brought down by rivers that rise and fall with the seasons, must cause variations in the resulting strata—alternations of colour or quality in the successive laminæ. Beds formed from the detritus of shores worn down and carried away by the waves, must similarly show periodic differences answering to the periodic winds of the locality. In so far as frost influences the rate of denudation, its recurrence is a factor in the rhythm of sedimentary deposits. And the geological changes produced

by glaciers and icebergs must similarly have their alternating periods of greater and less intensity.

There is evidence also that modifications in the Earth's crust due to igneous action have a certain periodicity. Volcanic eruptions are not continuous but intermittent, and as far as the data enable us to judge, have a certain average rate of recurrence; which rate of recurrence is complicated by rising into epochs of greater activity and falling into epochs of comparative quiescence. So too is it with earthquakes and the elevations or depressions caused by them. At the mouth of the Mississippi, the alternation of strata gives decisive proof of successive sinkings of the surface, that have taken place at tolerably equal intervals. Everywhere, in the extensive groups of conformable strata that imply small subsidences recurring with a certain average frequency, we see a rhythm in the action and reaction between the Earth's crust and its molten contents —a rhythm compounded with those slower ones shown in the termination of groups of strata, and the commencement of other groups not conformable to them. There is even reason for suspecting a geological periodicity that is immensely slower and far wider in its effects, namely, an alternation of those vast upheavals and submergencies by which continents are produced where there were oceans, and oceans where there were continents. For supposing, as we may fairly do, that the Earth's crust is throughout of tolerably equal thickness, it is manifested that such portions of it as become most depressed below the average level, must have their inner surfaces most exposed to the currents of molten matter circulating within, and will therefore undergo a larger amount of what may be called igneous denudation; while, conversely, the withdrawal of the inner surfaces from these currents where the Earth's crust is most elevated, will cause a thickening, more or less compensating the aqueous denudation going on externally. Hence those depressed areas over which the deepest oceans lie, being gradually thinned beneath and not covered by much sedimentary deposit above, will become areas of least resistance, and will then begin to yield to the upward pressure of the Earth's con-

tents; whence will result, throughout such areas, long-continued elevations, ceasing only when the reverse state of things has been brought about. Whether this speculation be well or ill founded, does not however affect the general conclusion. Apart from it we have sufficient evidence that geologic processes are rhythmical.

Perhaps nowhere are the illustrations of rhythm so numerous and so manifest as among the phenomena of life. Plants do not, indeed, usually show us any decided periodicities, save those determined by day and night and the seasons. But in animals we have a great variety of movements in which the alternation of opposite extremes goes on with all degrees of rapidity. The swallowing of food is effected by a wave of constriction passing along the œsophagus; its digestion is accompanied by a muscular action of the stomach that is also undulatory; and the peristaltic motion of the intestines is of like nature. The blood obtained from this food is propelled not in a uniform current but in pulses; and locomotion results from oscillating movements: even where it is apparently continuous, as in many minute forms, the microscope proves the vibration of cilia to be the agency by which the creature is moved smoothly forwards.

Primary rhythms of the organic actions are compounded with secondary ones of longer duration. These various modes of activity have their recurring periods of increase and decrease. We see this in the periodic need for food, and in the periodic need for repose. Each meal induces a more rapid rhythmic action of the digestive organs; the pulsation of the heart is accelerated; and the inspirations become more and more frequent. During sleep, on the contrary, these several movements slacken. So that in the course of the twenty-four hours, those small undulations, of which the different kinds of organic action are constituted, undergo one long wave of increase and decrease, complicated with several minor waves. Experiments have shown that there are still slower rises and falls of functional activity. Waste and assimilation are not balanced by every meal, but one or other maintains for some time a slight excess;

so that a person in ordinary health is found to undergo and increase or decrease weight during recurring intervals of tolerable equality. Beside these regular periods there are still longer and comparatively irregular ones; namely, those alternations of greater and less vigour, even healthy people experience. So inevitable are these oscillations that even men in training cannot be kept stationary at their highest power, but when they have reached it begin to retrograde. Further evidence of rhythm in the vital movements is furnished by invalids. Sundry disorders are named from the intermittent character of their symptoms. Even where the periodicity is not very marked, it is mostly traceable. Patients rarely if ever get uniformly worse; and convalescents have usually their days of partial relapse, or of less decided advance.

Aggregates of living creatures illustrate the general truth in other ways. If each species of organism be regarded as a whole, it displays two kinds of rhythm. Life as it exists in all the members of such species is an extremely complex kind of movement, more or less distinct from the kinds of movement which constitute life in other species. In each individual of the species, this extremely complex kind of movement begins, rises to its climax, declines, and ceases in death. And every successive generation thus exhibits a wave of that peculiar activity characterizing the species as a whole. The other form of rhythm is to be traced in that variation of number which each tribe of animals and plants is ever undergoing. Throughout the unceasing conflict between the tendency of a species to increase and the antagonistic tendencies, there is never an equilibrium: one always predominates. In the case even of a cultivated plant or domesticated animal, where artificial means are used to maintain the supply at a uniform level, we still see that oscillations of abundance and scarcity cannot be avoided. And among the creatures uncared for by man, such oscillations are usually more marked. After a race of organisms has been greatly thinned by enemies or lack of food, its surviving members become more favourably circumstanced than usual. During the decline in their numbers their food has grown relatively

more abundant; while their enemies have diminished from want of prey. The conditions thus remain for some time favourable to their increase; and they multiply rapidly. By and by their food is rendered relatively scarce, at the same time that their enemies have become more numerous; and the destroying influences being thus in excess, their numbers begin to diminish again. Yet one more rhythm, extremely slow in its action, may be traced in the phenomena of Life, contemplated under their most general aspect. The researches of palæontologists show that there have been going on, during the vast period of which our sedimentary rocks bear record, successive changes of organic forms. Species have appeared, become abundant, and then disappeared. Genera, at first constituted of but few species, have for a time gone on growing more multiform; and then have begun to decline in the number of their subdivisions: leaving at last but one or two representatives, or none at all. During longer epochs whole orders have thus arisen, culminated and dwindled away. And even those wider divisions containing many orders have similarly undergone a gradual rise, a high tide, and a long-continued ebb. The stalked *Crinoidea*, for example, which, during the carboniferous epoch, became abundant, have almost disappeared: only a single species being extant. Once a large family of molluscs, the *Brachiopoda* have now become rare. The shelled Cephalopods, at one time dominant among the inhabitants of the ocean, both in number of forms and of individuals, are in our day nearly extinct. And after an "age of reptiles," there has come an age in which reptiles have been in great measure supplanted by mammals. Whether these vast rises and falls of different kinds of life ever undergo anything approaching to repetitions (which they may possibly do in correspondence with those vast cycles of elevation and subsidence that produce continents and oceans), it is sufficiently clear that Life on the Earth has not progressed uniformly, but in immense undulations.

It is not manifest that the changes of consciousness are in any sense rhythmical. Yet here, too, analysis proves both that the mental state existing at any moment is not uniform, but

is decomposable into rapid oscillations; and also that mental states pass through longer intervals of increasing and decreasing intensity.

Though while attending to any single sensation, or any group of related sensations constituting the consciousness of an object, we seem to remain for the time in a persistent and homogeneous condition of mind, a careful self-examination shows that this apparently unbroken mental state is in truth traversed by a number of minor states, in which various other sensations and perceptions are rapidly presented and disappear. From the admitted fact that thinking consists in the establishment of relations, it is a necessary corollary that the maintenance of consciousness in any one state to the entire exclusion of other states, would be a cessation of thought, that is, of consciousness. So that any seemingly continuous feeling, say of pressure, really consists of portions of that feeling perpetually recurring after the momentary intrusion of other feelings and ideas—quick thoughts concerning the place where it is felt, the external object producing it, its consequences, and other things suggested by association. Thus there is going on an extremely rapid departure from, and return to, that particular mental state which we regard as persistent. Besides the evidence of rhythm in consciousness which direct analysis thus affords, we may gather further evidence from the correlation between feeling and movement. Sensations and emotions expend themselves in producing muscular contractions. If a sensation or emotion were strictly continuous, there would be a continuous discharge along those motor nerves acted upon. But so far as experiments with artificial stimuli enable us to judge, a continuous discharge along the nerve leading to a muscle does not contract it: a broken discharge is required—a rapid succession of shocks. Hence muscular contraction presupposes that rhythmic state of consciousness which direct observation discloses. A much more conspicuous rhythm, having longer waves, is seen during the outflow of emotion into dancing, poetry, and music. The current of mental energy that shows itself in these modes of bodily action, is not continuous, but

falls into a succession of pulses. The measure of a dance is produced by the alternation of strong muscular contractions with weaker ones; and, save in measures of the simplest order such as are found among barbarians and children, this alternation is compounded with longer rises and falls in the degree of muscular excitement. Poetry is a form of speech which results when the emphasis is greatly recurrent; that is, when the muscular effort of pronunciation has definite periods of greater and less intensity—periods that are complicated with others of like nature answering to the successive verses. Music, in still more various ways, exemplifies the law. There are recurring bars, in each of which there is a primary and a secondary beat. There is the alternate increase and decrease of muscular strain, implied by the ascents and descents to the higher and lower notes—ascents and descents composed of smaller waves, breaking the rises and falls of the larger ones, in a mode peculiar to each melody. And then we have, further, the alternation of *piano* and *forte* passages. That these several kinds of rhythm, characterizing æsthetic expression, are not, in the common sense of the word, artificial, but are intenser forms of an undulatory movement habitually generated by feeling in its bodily discharge, is shown by the fact that they are all traceable in ordinary speech; which in every sentence has its primary and secondary emphases, and its cadence containing a chief rise and fall complicated with subordinate rises and falls; and which is accompanied by a more or less oscillatory action of the limbs when the emotion is great. Still longer undulations may be observed by every one, in himself and in others, on occasions of extreme pleasure or extreme pain. Note, in the first place, that pain having its origin in bodily disorder, is nearly always perceptibly rhythmical. During hours in which it never actually ceases, it has its variations of intensity-fits or paroxysms; and then after these hours of suffering there usually come hours of comparative ease. Moral pain has the like smaller and larger waves. One possessed by intense grief does not utter continuous moans, or shed tears with an equable rapidity; but these signs of passion come in recurring bursts. Then after a time

during which stronger and weaker waves of emotion alternate, there comes a calm—a time of comparative deadness; to which again succeeds another interval, when dull sorrow rises afresh into acute anguish, with its series of paroxysms. Similarly in great delight, especially as manifested by children who have its display under less control, there are visible variations in the intensity of feeling shown—fits of laughter and dancing about, separated by pauses in which smiles, and other slight manifestations of pleasure, suffice to discharge the lessened excitement. Nor are there wanting evidences of mental undulations greater in length than any of these—undulations which take weeks, or months, or years, to complete themselves. We continually hear of moods which recur at intervals. Very many persons have their epochs of vivacity and depression. There are periods of industry following periods of idleness; and times at which particular subjects or tastes are cultivated with zeal, alternating with times at which they are neglected. Respecting which slow oscillations, the only qualification to be made is, that being affected by numerous influences, they are comparatively irregular.

In nomadic societies the changes of place, determined as they usually are by the exhaustion or failure of the supply of food, are periodic; and in many cases show a recurrence answering to the seasons. Each tribe that has become in some degree fixed in its locality goes on increasing, till under the pressure of unsatisfied desires there results migration of some part of it to a new region—a process repeated at intervals. From such excesses of population, and such successive waves of migration, come conflicts with other tribes; which are also increasing and tending to diffuse themselves. This antagonism, like all others, results not in an uniform motion, but in an intermittent one. War, exhaustion, recoil—peace, prosperity, and renewed aggression: we see here the alternation more or less discernible in the military activities of both savage and civilized nations. And irregular as is this rhythm, it is not more so than the different sizes of the societies and the extremely involved causes of variation in their strengths would lead us to anticipate.

Passing from external to internal changes, we meet with this backward and forward movement under many forms. In the currents of commerce it is especially conspicuous. Exchange during early times is almost wholly carried on at fairs, held at long intervals in the chief centers of population. The flux and reflux of people and commodities which each of these exhibits becomes more frequent as national development leads to greater social activity. The more rapid rhythm of weekly markets begins to supersede the slow rhythm of fairs. And eventually the process of exchange becomes at certain places so active, as to bring about daily meetings of buyers and sellers—a daily wave of accumulation and distribution of cotton, or corn, or capital. If from exchange we turn to production and consumption, we see undulations, much longer indeed in their periods, but almost equally obvious. Supply and demand are never completely adapted to each other; but each of them from time to time in excess, leads presently to an excess of the other. Farmers who have one season produced wheat very abundantly, are disgusted with the consequent low price; and next season, sowing a much smaller quantity, bring to market a deficient crop; whence follows a converse effect. Consumption undergoes parallel undulations that need not be specified. The balancing of supplies between different districts, too, entails analogous oscillations. A place at which some necessary of life is scarce, becomes a place to which currents of it are set up from other places where it is relatively abundant; and these currents from all sides lead to a wave of accumulation where they meet—a glut: whence follows a recoil—a partial return of the currents. But the undulatory character of these actions is perhaps best seen in the rises and falls of prices. These, given in numerical measures which may be tabulated and reduced to diagrams, show us in the clearest manner how commercial movements are compounded of oscillations of various magnitudes. The price of consols or the price of wheat, as thus represented, is seen to undergo vast ascents and descents whose highest and lowest points are reached only in the course of years. These largest waves of variation are broken by others extending

over periods of perhaps many months. On these again come others having a week or two's duration. And were the changes marked in greater detail, we should have the smaller undulations that take place each day, and the still smaller ones which brokers telegraph from hour to hour. The whole outline would show a complication like that of a vast ocean-swell, on whose surface there rise large billows, which themselves bear waves of moderate size, covered by wavelets, that are roughened by a minute ripple. Similar diagrammatic representations of births, marriages, and deaths, of disease, of crime, of pauperism, exhibit involved conflicts of rhythmical motions throughout society under these several aspects.

There are like characteristics in social changes of a more complex kind. Both in England and among continental nations, the action and reaction of political progress have come to be generally recognized. Religion, besides its occasional revivals of smaller magnitude, has its long periods of exultation and depression—generations of belief and self-mortification, following generations of indifference and laxity. There are poetical epochs, and epochs in which the sense of the beautiful seems almost dormant. Philosophy, after having been awhile predominant, lapses for a long season into neglect; and then again slowly revives. Each science has its eras of deductive reasoning, and its eras when attention is chiefly directed to collecting and colligating facts. And how in such minor but more obtrusive phenomena as those of fashion, there are ever going on oscillations from one extreme to the other, is a trite observation.

As may be foreseen, social rhythms well illustrate the irregularity that results from combination of many causes. Where the variation are those of one simple element in national life, as the supply of a particular commodity, we do indeed witness a return, after many involved movements, to a previous condition—the price may become what it was before: implying a like relative abundance. But where the action is one into which many factors enter, there is never a recurrence of exactly the same state. A political reaction never brings round

just the same form of things. The rationalism of the present day differs widely from the rationalism of the last century. And though fashion from time to time revives extinct types of dress, these always reappear with decided modifications.

The universality of this principle suggests a question like that raised in foregoing cases. Rhythm being manifested in all forms of movement, we have reason to suspect that it is determined by some primordial condition to action in general. The tacit implication is that it is deducible from the persistence of force. This we shall find to be the fact.

When the prong of a tuning-fork is pulled on one side by the finger, a certain extra tension is produced among its cohering particles; which resist any forces that draws them out of their state of equilibrium. As much force as the finger exerts in pulling the prong aside, so much opposing force is brought into play among the cohering particles. Hence, when the prong is liberated, it is urged back by a force equal to that used in deflecting it. When, therefore, the prong reaches its original position, the force impressed on it during its recoil has generated in it a corresponding amount of momentum—an amount of momentum nearly equivalent, that is, to the force originally impressed (nearly, we must say, because a certain portion has gone in communicating motion to the air, and a certain other portion has been transformed into heat). This momentum carries the prong beyond the position of rest, nearly as far as it was originally drawn in the reverse direction; until at length, being gradually used up in producing an opposing tension among the particles, it is all lost. The opposing tension into which the expended momentum has been transformed, then generates a second recoil; and so on continually—the vibration eventually ceasing only because at each movement a certain amount of force goes in creating atmospheric and ethereal undulations. Now it needs but to contemplate this repeated action and reaction to see that it is, like every action and reaction, a consequence of the persistence of force. The force exerted by the finger in bending the prong cannot disappear. Under what

form then does it exist? It exists under the form of that cohesive tension which it has generated among the particles. This cohesive tension cannot cease without an equivalent result. What is its equivalent result? The momentum generated in the prong while being carried back to its position of rest. This momentum too—what becomes of it? It must either continue as a momentum, or produce some correlative force of equal amount. It cannot continue as a momentum, since change of place is resisted by the cohesion of the parts; and thus it gradually disappears by being transformed into tension among these parts. This is re-transformed into the equivalent momentum: and so on continuously. If instead of motion that is directly antagonized by the cohesion of matter, we consider motion through space, the same truth presents itself under another form. Though here no opposing force seems at work, and therefore no cause of rhythm is apparent, yet its own accumulated momentum must eventually carry the moving body beyond the body attracting it; and so must become a force at variance with that which generated it. From this conflict, rhythm necessarily results as in the foregoing case. The force embodied as momentum in a given direction cannot be destroyed; and if it eventually disappears, it reappears in the reaction on the retarding body; which begins afresh to draw the now arrested mass back from its aphelion. The only conditions under which there could be absence of rhythm—the only conditions, that is, under which there could be a continuous motion through space in the same straight line forever, would be the existence of an infinity void of everything but the moving body. And neither of these conditions can be represented in thought. Infinity is inconceivable; and so also is a motion which never had a commencement in some pre-existing source of power.

Thus, then, rhythm is a necessary characteristic of all motion. Given the co-existence everywhere of antagonist forces—a postulate which, as we have seen, is necessitated by the form of our experience—and rhythm is an inevitable corollary form from the persistence of force.

QUESTIONS AND EXERCISES

Spencer's chapter on rhythm is offered as an example of effective method in handling large masses of details. Out of a heterogeneous and disorderly mass of facts and phenomena, the writer has found an underlying principle which reduces them to system. An exposition that merely details a lot of facts, no matter how interesting they may be in themselves, without bringing them into common bearing with each other, is unsatisfactory. The successful explanation makes its readers see the subject clearly and luminously; the scattered facts and instances are given new meaning by being brought under a single principle. "One might liken the way in which a lot of miscellaneous facts takes on new meaning when you understand the general principles behind them, to the way in which if you put a magnet under a paper of iron filings, the filings will immediately fall into a pattern of concentric circles: so when you understand your facts, you have an almost physical sense of simplification and a consequent saving of time and attention" (Gardiner, *The Forms of Prose Literature*, p. 26).

1. Examine the chapter first from the standpoint of careful selection of examples of the law. Do the illustrations offered cover a sufficiently broad field to make the universality of the principle conclusive? Do you think of any important fields of knowledge that have been overlooked? Any in which the application of the principle is not quite evident? How far would Spencer's conclusions be impaired by a single typical case of motion which was not rhythmical? Read Emerson's essay entitled Compensation. Has it anything in common with this discussion of Spencer's? Are the conclusions in the two cases identical?

2. Attention should next be directed to the arrangement of details and groups of details. Do you note any progression? Could a rearrangement of details be secured without in any way altering the effectiveness of the presentation? In order to answer this question, first make a list of the examples given; then try to determine why they were put in the present order. Are some of the examples more important than others? Do some offer greater difficulties of presentation? Are such given positions of emphasis? Are they presented at greater length than the others? The main conclusion in the chapter is that rhythm is universal; are there any secondary conclusions? What are they? Are their positions in the chapter unalterable?

3. It should be noted that the chapter, though strictly scientific, yet has a certain literary flavor—the details, in addition to their office in advancing the abstract theory, seem to have a value in and of themselves. This is especially noticeable in the descriptive character of the first paragraph, though to a certain extent it is felt throughout the chapter.

Exercise 1. Show by a careful selection and effective ordering of a series of examples, the fact that most great men have been of humble origin; establish in like manner the universality of the law of gravitation or the law of the conservation of energy.

Exercise 2. Show by series of examples, carefully grouped, that the most useful and important work of men's lives has been accomplished after they have passed the age of forty. For data see the *Century Magazine*, vol. LXXV, p. 934, and vol. LXXVI, p. 113.

STRUGGLE FOR EXISTENCE [1]

CHARLES DARWIN

BEFORE entering on the subject of this chapter, I must make a few preliminary remarks, to show how the struggle for existence bears on Natural Selection. It has been seen in the last chapter that amongst organic beings in a state of nature there is some individual variability: indeed I am not aware that this has ever been disputed. It is immaterial for us whether a multitude of doubtful forms be called species or sub-species or varieties; what rank, for instance, the two or three hundred doubtful forms of British plants are entitled to hold, if the existence of any well-marked varieties be admitted. But the mere existence of individual variability and of some few well-marked varieties, though necessary as the foundation for the work, helps us but little in understanding how species arise in nature. How have all those exquisite adaptations of one part of the organization to another part, and to the conditions of life, and

[1] Reprinted from *The Origin of Species*, published by Messrs. D. Appleton & Co.

of one organic being to another being, been perfected? We see these beautiful co-adaptations most plainly in the woodpecker and the mistletoe; and only a little less plainly in the humblest parasite which clings to the hairs of a quadruped or feathers of a bird; in the structure of the beetle which dives through the water; in the plumed seed which is wafted by the gentlest breeze; in short, we see beautiful adaptations everywhere and in every part of the organic world.

Again, it may be asked, how is it that varieties, which I have called incipient species, become ultimately converted into good and distinct species which in most cases obviously differ from each other far more than do the varieties of the same species? How do those groups of species which constitute what are called distinct genera, and which differ from each other more than do the species of the same genus, arise? All these results, as we shall more fully see in the next chapter, follow from the struggle for life. Owing to this struggle, variations, however slight and from whatever cause proceeding, if they be in any degree profitable to the individuals of a species, in their infinitely complex relations to other organic beings and to their physical conditions of life, will tend to the preservation of such individuals, and will generally be inherited by the offspring. The offspring, also, will thus have a better chance of surviving, for, of the many individuals of any species which are periodically born, but a small number can survive. I have called this principle, by which each slight variation, if useful, is preserved, by the term Natural Selection, in order to mark its relation to man's power of selection. But the expression often used by Mr. Herbert Spencer of the Survival of the Fittest is more accurate, and is sometimes equally convenient. We have seen that man by selection can certainly produce great results, and can adapt organic beings to his own uses, through the accumulation of slight but useful variations, given to him by the hand of Nature. But Natural Selection, as we shall hereafter see, is a power incessantly ready for action, and is as immeasurably superior to man's feeble efforts, as the works of Nature to those of Art.

We will now discuss in a little more detail the struggle for

existence. In my future work this subject will be treated, as it well deserves, at greater length. The elder De Candolle and Lyell have largely and philosophically shown that all organic beings are exposed to severe competition. In regard to plants, no one has treated this subject with more spirit and ability than W. Herbert, Dean of Manchester, evidently the result of his great horticultural knowledge. Nothing is easier than to admit in words the truth of the universal struggle for life, or more difficult—at least I have found it so—than constantly to bear this conclusion in mind. Yet unless it be thoroughly engrained in the mind, the whole economy of nature, with every fact on distribution, rarity, abundance, extinction, and variation, will be dimly seen or quite misunderstood. We behold the face of nature bright with gladness, we often see superabundance of food; we do not see or we forget, that the birds which are idly singing round us mostly live on insects or seeds, and are thus constantly destroying life; or we forget how largely these songsters, or their eggs, or their nestlings, are destroyed by birds and beasts of prey; we do not always bear in mind, that, though food may be now superabundant, it is not so at all seasons of each recurring year.

The Term, Struggle for Existence, used in a large sense

I should premise that I use this term in a large and metaphorical sense including dependence of one being on another, and including (which is more important) not only the life of the individual, but success in leaving progeny. Two canine animals, in a time of dearth, may be truly said to struggle with each other which shall get food and live. But a plant on the edge of a desert is said to struggle for life against the drought, though more properly it should be said to be dependent on the moisture. A plant which annually produces a thousand seeds, of which only one of an average comes to maturity, may be more truly said to struggle with the plants of the same and other kinds which already clothe the ground. The mistletoe is dependent on the apple and a few other trees, but can only in a far-fetched sense be said to struggle with these trees, for, if too many of

these parasites grow on the same tree, it languishes and dies. But several seedling mistletoes, growing close together on the same branch, may be more truly said to struggle with each other. As the mistletoe is disseminated by birds, its existence depends on them; and it may metaphorically be said to struggle with other fruit-bearing plants, in tempting the birds to devour and thus disseminate its seeds. In these several senses, which pass into each other, I use for convenience' sake the general term of Struggle for Existence.

Geometrical Ratio of Increase

A struggle for existence inevitably follows from the high rate at which all organic beings tend to increase. Every being, which during its natural lifetime produces several eggs or seeds, must suffer destruction during some period of its life, and during some season or occasional year, otherwise, on the principle of geometrical increase, its numbers would quickly become so inordinately great that no country could support the product. Hence, as more individuals are produced than can possibly survive, there must in every case be a struggle for existence, either one individual with another of the same species, or with the individuals of distinct species, or with the physical conditions of life. It is the doctrine of Malthus applied with manifold force to the whole animal and vegetable kingdoms; for in this case there can be no artificial increase of food, and no prudential restraint from marriage. Although some species may be now increasing, more or less rapidly, in numbers, all cannot do so, for the world would not hold them.

There is no exception to the rule that every organic being naturally increases at so high a rate, that, if not destroyed, the earth would soon be covered by the progeny of a single pair. Even slow-breeding man has doubled in twenty-five years, and at this rate, in less than a thousand years, there would literally not be standing room for his progeny. Linnæus has calculated that if an annual plant produced only two seeds—and there is no plant so unproductive as this—and their seedlings next year produced two, and so on, then in twenty years there should be

a million plants. The elephant is reckoned the slowest breeder of all known animals, and I have taken some pains to estimate its probable minimum rate of natural increase; it will be safe to assume that it begins breeding when thirty years old, and goes on breeding till ninety years old, bringing forth six young in the interval, and surviving till one hundred years old; if this be so, after a period of from 740 to 750 years there would be nearly ninety million elephants alive descended from the first pair.

But we have better evidence on this subject than mere theoretical calculations, namely, the numerous recorded cases of the astonishingly rapid increase of various animals in a state of nature, when circumstances have been favorable to them during two or three following seasons. Still more striking is the evidence from our domestic animals of many kinds which have run wild in several parts of the world; if the statements of the rate of increase of slow-breeding cattle and horses in South America, and latterly in Australia, had not been well authenticated, they would have been incredible. So it is with plants; cases could be given of introduced plants which have become common throughout whole islands in a period of less than ten years. Several of the plants, such as the cardoon and a tall thistle, which are now the commonest over the whole plains of La Plata, clothing square leagues of surface almost to the exclusion of every other plant, have been introduced from Europe; and there are plants which now range in India, as I hear from Dr. Falconer, from Cape Comorin to the Himalaya, which have been imported from America since its discovery. In such cases, and endless others could be given, no one supposes that the fertility of the animals or plants has been suddenly and temporarily increased in any sensible degree. The obvious explanation is that the conditions of life have been highly favorable, and that there has consequently been less destruction of the old and young, and that nearly all of the young have been enabled to breed. Their geometrical ratio of increase, the result of which never fails to be surprising, simply explains their extraordinarily rapid increase and wide diffusion in their new homes.

In a state of nature almost every full-grown plant annually produces seed, and amongst animals there are very few which do not annually pair. Hence we may confidently assert, that all plants and animals are tending to increase at a geometrical ratio—that all would rapidly stock every station in which they could anyhow exist—and that this geometrical tendency to increase must be checked by destruction at some period of life. Our familiarity with the larger domestic animals tends, I think, to mislead us; we see no great destruction falling on them, but we do not keep in mind that thousands are annually slaughtered for food, and that in a state of nature an equal number would have somehow to be disposed of.

The only difference between organisms which annually produce eggs or seeds by the thousand, and those which produce extremely few, is, that the slow breeders would require a few more years to people, under favorable conditions, a whole district, let it be ever so large. The condor lays a couple of eggs and the ostrich a score, and yet in the same country the condor may be the more numerous of the two; the Fulmar petrel lays but one egg, yet it is believed to be the most numerous bird in the world. One fly deposits hundreds of eggs, and another, like the hippobosca, a single one; but this difference does not determine how many individuals of the two species can be supported in a district. A large number of eggs is of some importance to those species which depend on a fluctuating amount of food, for it allows them rapidly to increase in number. But the real importance of a large number of eggs or seeds is to make up for such destruction at some period of life; and this period, in the great majority of cases, is an early one. If an animal can in any way protect its own eggs or young, a small number may be produced, and yet the average stock be fully kept up; but if many eggs or young are destroyed, many must be produced, or the species will become extinct. It would suffice to keep up the full number of a tree, which lived on an average for a thousand years, if a single seed were produced once in a thousand years, supposing that this seed were never destroyed, and could be ensured to germinate in a fitting place. So that, in all cases,

the average number of any animal or plant depends only directly on the number of its eggs or seeds.

In looking at Nature, it is most necessary to keep the foregoing consideration always in mind—never to forget that every single organic being may be said to be striving to the utmost to increase in numbers; that each lives by a struggle at some period of its life; that heavy destruction inevitably falls either on the young or old, during each generation or at recurrent intervals. Lighten any check, mitigate the destruction ever so little, and the number of the species will almost instantaneously increase to any amount.

Nature of the Checks to Increase

The causes which check the natural tendency of each species to increase are most obscure. Look at the most vigorous species; by as much as it swarms in numbers, by so much will it tend to increase still further. We know not exactly what the checks are even in a single instance. Nor will this surprise anyone who reflects how ignorant we are on this head, even in regard to mankind, although so incomparably better known than any other animal. This subject of the checks to increase has been ably treated by several authors, and I hope in a future work to discuss it at considerable length, more especially in regard to the feral animals of South America. Here I will make only a few remarks, just to recall to the reader's mind some of the chief points. Eggs or very young animals seem generally to suffer most, but this is not invariably the case. With plants there is a vast destruction of seeds, but, from some observations which I have made, it appears that the seedlings suffer most from germinating in ground already thickly stocked with other plants. Seedlings, also, are destroyed in vast numbers by various enemies; for instance, on a piece of ground three feet long and two wide, dug and cleared, and where there could be no choking from other plants, I marked all the seedlings of our native weeds as they came up, and out of 357 no less than 295 were destroyed, chiefly by slugs and insects. If turf which has long been mown, and the case would be the same with turf

closely browsed by quadrupeds, be let to grow, the more vigorous plants gradually kill the less vigorous, though fully grown plants; thus out of twenty species on a little plot of mown turf (three feet by four) nine species perished, from the other species being allowed to grow up freely.

The amount of food for each species of course gives the extreme limit to which each can increase; but very frequently it is not the obtaining food, but the serving as prey to other animals, which determines the average numbers of a species. Thus, there seems to be little doubt that the stock of partridges, grouse, and hares on any large estate depends chiefly on the destruction of vermin. If not one head of game were shot during the next twenty years in England, and, at the same time, if no vermin were destroyed, there would, in all probability, be less game than at present, although hundreds of thousands of game animals are now annually shot. On the other hand, in some cases, as with the elephant, none are destroyed by beasts of prey; for even the tiger in India rarely dares to attack a young elephant protected by its dam.

Climate plays an important part in determining the average number of a species, and periodical seasons of extreme cold or drought seem to be the most effective of all checks. I estimated (chiefly from the greatly reduced numbers of nests in the spring) that the winter of 1854–5 destroyed four-fifths of the birds in my own grounds; and this is a tremendous destruction, when we remember that ten per cent. is an extraordinarily severe mortality from epidemics with man. The action of climate seems at first sight to be quite independent of the struggle for existence; but in so far as climate chiefly acts in reducing food, it brings on the most severe struggle between the individuals, whether of the same or of distinct species, which subsist on the same kind of food. Even when climate, for instance, extreme cold, acts directly, it will be the least vigorous individuals, or those which have got least food through the advancing winter, which will suffer most. When we travel from south to north, or from a damp region to a dry, we invariably see some species gradually getting rarer and rarer, and finally disappear-

ing; and the change of climate being conspicuous, we are tempted to attribute the whole effect to its direct action. But this is a false view; we forget that each species, even where it most abounds, is constantly suffering enormous destruction at some period of its life, from enemies or from competitors for the same place and food; and if these enemies or competitors be in the least degree favoured by any slight change of climate, they will increase in numbers; and as each area is already fully stocked with inhabitants, the other species must decrease. When we travel southward and see a species decreasing in numbers, we may feel sure that the cause lies quite as much in other species being favoured as in this one being hurt. So it is when we travel northward, but in a somewhat lesser degree, for the number of species of all kinds, and therefore of competitors, decreases northwards; hence in going northwards, or in ascending a mountain, we far oftener meet with stunted forms, due to the directly injurious action of climate, than we do in proceeding southwards or in descending a mountain. When we reach the Arctic regions, or snow-capped summits, or absolute deserts, the struggle for life is almost exclusively with the elements.

That climate acts in main part indirectly by favouring other species, we clearly see in the prodigious number of plants which in our gardens can perfectly well endure our climate, but which never become naturalised, for they cannot compete with our native plants nor resist destruction by our native animals.

When a species, owing to highly favourable circumstances, increases inordinately in numbers in a small tract, epidemics—at least—this seems generally to occur with our game animals—often ensue; and here we have a limiting check independent of the struggle for life. But even some of these so-called epidemics appear to be due to parasitic worms, which have from some cause, possibly in part through facility of diffusion amongst the crowded animals, been disproportionately favoured; and here comes in a sort of struggle between the parasite and its prey.

On the other hand, in many cases, a large stock of individuals of the same species, relatively to the numbers of its enemies, is absolutely necessary for its preservation. Thus we can

easily raise plenty of corn and rape-seed, &c., in our fields, because the seeds are in great excess compared with the number of birds which feed on them; nor can the birds, though having a superabundance of food at this one season, increase in number proportionally to the supply of seed, as their numbers are checked during the winter; but anyone who has tried knows how troublesome it is to get seed from a few wheat or other such plants in a garden: I have in this case lost every single seed. This view of the necessity of a large stock of the same species for its preservation explains, I believe, some singular facts in nature, such as that of very rare plants being sometimes extremely abundant, in the few spots where they do exist; and that of some social plants being social, that is abounding in individuals, even on the extreme verge of their range. For in such cases, we may believe, that a plant could exist only where the conditions of its life were so favourable that many could exist together, and thus save the species from utter destruction. I should add that the good effects of intercrossing, and the ill effects of close interfreeding, no doubt come into play in many of these cases; but I will not here enlarge on this subject.

Complex Relations of all Animals and Plants to each other in the Struggle for Existence

Many cases are on record showing how complex and unexpected are the checks and relations between organic beings, which have to struggle together in the same country. I will give only a single instance, which, though a simple one, interested me. In Staffordshire, on the estate of a relation, where I had ample means of investigation, there was a large and extremely barren heath, which had never been touched by the hand of man; but several hundred acres of exactly the same nature had been enclosed twenty-five years previously and planted with Scotch fir. The change in the native vegetation of the planted part of the heath was most remarkable, more than is generally seen in passing from one quite different soil to another: not only the proportional numbers of the heath plants were wholly changed, but twelve species of plants (not

counting grasses and carices) flourished in the plantations, which could not be found on the heath. The effect on the insects must have been still greater, for six insectivorous birds were very common in the plantations, which were not to be seen on the heath; and the heath was frequented by two or three distinct insectivorous birds. Here we see how potent has been the effect of the introduction of a single tree, nothing whatever else having been done, with the exception of the land having been enclosed, so that cattle could not enter. But how important an element enclosure is, I plainly saw near Farnham, in Surrey. Here there are extensive heaths, with a few clumps of old Scotch firs on the distant hill-tops: within the last ten years large spaces have been enclosed, and self-sown firs are now springing up in multitudes, so close together that all cannot live. When I ascertained that these young trees had not been sown or planted, I was so much surprised at their numbers that I went to several points of view, whence I could examine hundreds of acres of the unenclosed heath, and literally I could not see a single Scotch fir, except the old planted clumps. But on looking closely between the stems of the heath, I found a multitude of seedlings and little trees which had been perpetually browsed down by the cattle. In one square yard, at a point some hundred yards distant from one of the old clumps, I counted thirty-two little trees; and one of them, with twenty-six rings of growth, had during many years tried to raise its head above the stems of the heath, and had failed. No wonder that, as soon as the land was enclosed, it became thickly clothed with vigorously growing young firs. Yet the heath was so extremely barren and so extensive that no one would ever have imagined that cattle would have so closely and effectually searched it for food.

Here we see that cattle absolutely determine the existence of the Scotch fir; but in several parts of the world insects determine the existence of cattle. Perhaps Paraguay offers the most curious instance of this; for here neither cattle nor horses nor dogs have ever run wild, though they swarm southward and northward in a feral state; and Azara and Rengger have shown

that this is caused by the greater number in Paraguay of a certain fly, which lays its eggs in the navels of these animals when first born. The increase of these flies, numerous as they are, must be habitually checked by some means, probably by other parasitic insects. Hence, if certain insectivorous birds were to decrease in Paraguay, the parasitic insects would probably increase; and this would lessen the number of the navel-frequenting flies—then cattle and horses would become feral, and this would certainly greatly alter (as indeed I have observed in parts of South America) the vegetation: this again would largely affect the insects; and this, as we have just seen in Staffordshire, the insectivorous birds, and so onwards in ever-increasing circles of complexity. Not that under nature the relations will ever be as simple as this. Battle within battle must be continually recurring with varying success; and yet in the long run the forces are so nicely balanced, that the face of nature remains for long periods of time uniform, though assuredly the merest trifle would give the victory to one organic being over another. Nevertheless, so profound is our ignorance, and so high our presumption, that we marvel when we hear of the extinction of an organic being; and as we do not see the cause, we invoke cataclysms to desolate the world, or invent laws on the duration of the forms of life!

I am tempted to give one more instance showing how plants and animals remote in the scale of nature are bound together by a web of complex relations. I shall hereafter have occasion to show that the exotic Lobelia fulgens is never visited in my garden by insects, and consequently, from its peculiar structure, never sets a seed. Nearly all our orchidaceous plants absolutely require the visits of insects to remove their pollen-masses and thus to fertilise them. I find from experiments that humble-bees are almost indispensable to the fertilisation of the heartsease (Violo tricolor), for other bees do not visit this flower. I have also found that the visits of bees are necessary for the fertilisation of some kinds of clover; for instance, 20 heads of Dutch clover (Trifolium repens) yielded 2,290 seeds, but 20 other heads protected from bees produced not one. Again, 100 heads of red

clover (T. pratense) produced 2,700 seeds, but the same number of protected heads produced not a single seed. Humble-bees alone visit red clover, as other bees cannot reach the nectar. It has been suggested that moths may fertilise the clovers; but I doubt whether they could do so in the case of the red clover, from their weight not being sufficient to depress the wing petals. Hence we may infer as highly probable that, if the whole genus of humble-bees became extinct or very rare in England, the heartsease and red clover would become very rare, or wholly disappear. The number of humble-bees in any district depends in a great measure upon the number of field-mice, which destroy their combs and nests; and Col. Newman, who has long attended to the habits of humble-bees, believes that "more than two-thirds of them are thus destroyed all over England." Now the number of mice is largely dependent, as every one knows, on the number of cats; and Col. Newman says, "Near villages and small towns I have found the nests of humble-bees more numerous than elsewhere, which I attribute to the number of cats that destroy the mice." Hence it is quite credible that the presence of a feline animal in large numbers in a district might determine, through the intervention first of mice and then of bees, the frequency of certain flowers in that district!

In the case of every species, many different checks, acting at different periods of life, and during different seasons of years, probably come into play; some one check or some few being generally the most potent; but all will concur in determining the average number or even the existence of the species. In some cases it can be shown that widely different checks act on the same species in different districts. When we look at the plants and bushes clothing an entangled bank, we are tempted to attribute their proportional numbers and kinds to what we call chance. But how false a view is this! Every one has heard that when an American forest is cut down a very different vegetation springs up; but it has been observed that ancient Indian ruins in the Southern United States, which must formerly have been cleared of trees, now display the same beautiful

diversity and proportion of kinds as in the surrounding virgin forest. What a struggle must have gone on during long centuries between the several kinds of trees each annually scattering its seeds by the thousand; what war between insect and insect—between insects, snails, and other animals with birds and beasts of prey—all striving to increase, all feeding on each other, or on the trees, their seeds and seedlings, or on the other plants which first clothed the ground and thus checked the growth of the trees! Throw up a handful of feathers, and all fall to the ground according to definite laws; but how simple is the problem where each shall fall compared to that of the action and reaction of the innumerable plants and animals which have determined, in the course of centuries, the proportional numbers and kinds of trees now growing on the old Indian ruins!

The dependency of one organic being on another, as of a parasite on its prey, lies generally between beings remote in the scale of nature. This is likewise sometimes the case with those which may be strictly said to struggle with each other for existence, as in the case of locusts and grass-feeding quadrupeds. But the struggle will almost invariably be most severe between the individuals of the same species, for they frequent the same districts, require the same food, and are exposed to the same dangers. In the case of varieties of the same species, the struggle will generally be almost equally severe, and we sometimes see the contest soon decided; for instance, if several varieties of wheat be sown together, and the mixed seed be resown, some of the varieties which best suit the soil or climate, or are naturally the most fertile, will beat the others and so yield more seed, and will consequently in a few years supplant the other varieties. To keep up a mixed stock of even such extremely close varieties as the variously-coloured sweet peas, they must be each year harvested separately, and the seed then mixed in due proportion, otherwise the weaker kinds will steadily decrease in number and disappear. So again with the varieties of sheep; it has been asserted that certain mountain varieties will starve out other mountain varieties, so that they cannot be kept together. The same result has followed from keeping together different varie-

ties of the medicinal leech. It may even be doubted whether the varieties of any of our domestic plants or animals have so exactly the same strength, habits, and constitution, that the original properties of a mixed stock (crossing being prevented) could be kept up for half a dozen generations, if they were allowed to struggle together, in the same manner as beings in a state of nature, and if the seed or young were not annually preserved in due proportion.

Struggle for Life most severe between Individuals and Varieties of the same Species

As the species of the same genus usually have, though by no means invariably, much similarity in habits and constitution, and always in structure, the struggle will generally be more severe between them, if they come into competition with each other, than between the species of distinct genera. We see this in the recent extension over parts of the United States of one species of swallow having caused the decrease of another species. The recent increase of the missel-thrush in parts of Scotland has caused the decrease of the song thrush. How frequently we hear of one species of rat taking the place of another species under the most different climates! In Russia the small Asiatic cock-roach has everywhere driven before it its great congener. In Australia the imported hive-bee is rapidly exterminating the small, stingless native bee. One species of charlock has been known to supplant another species; and so in other cases. We can dimly see why the competition should be most severe between allied forms, which fill nearly the same place in the economy of nature; but probably in no one case could we precisely say why one species has been victorious over another in the great battle of life.

A corollary of the highest importance may be deduced from the foregoing remarks, namely, that the structure of every organic being is related, in the most essential yet often hidden manner, to that of all the other organic beings, with which it comes into competition for food or residence, or from which it has to escape, or on which it preys. This is obvious in the

structure of the teeth and talons of the tiger; and in that of the legs and claws of the parasite which clings to the hair on the tiger's body. But in the beautifully plumed seed of the dandelion, and in the flattened and fringed legs of the water beetle, the relation seems at first confined to the elements of air and water. Yet the advantage of plumed seeds no doubt stands in the closest relation to the land being already thickly clothed with other plants; so that the seeds may be widely distributed and fall on unoccupied ground. In the water beetle, the structure of its legs, so well adapted for diving, allows it to compete with other aquatic insects, to hunt for its own prey, and to escape serving as prey to other animals.

The store of nutriment laid up within the seeds of many plants seems at first sight to have no sort of relation to other plants. But from the strong growth of young plants produced from such seeds, as peas and beans, when sown in the midst of long grass, it may be suspected that the chief use of the nutriment in the seeds is to favour the growth of the seedlings, whilst struggling with other plants growing vigorously all around.

Look at a plant in the midst of its range, why does it not double or quadruple its numbers? We know that it can perfectly well withstand a little more heat or cold, dampness or dryness, for elsewhere it ranged into slightly hotter or colder, damper or drier districts. In this case we can clearly see that if we wish in imagination to give the plant the power of increasing in number, we should have to give it some advantage over its competitors, or over the animals which prey on it. On the confines of its geographical range, a change of constitution with respect to climate would clearly be an advantage to our plant; but we have reason to believe that only a few plants or animals range so far, that they are destroyed exclusively by the rigour of the climate. Not until we reach the extreme confines of life, in the Arctic regions or on the borders of an utter desert, will competition cease. The land may be extremely cold or dry, yet there will be competition between some few species, or between the individuals of the same species, for the warmest or dampest spots.

Hence we can see that when a plant or animal is placed in a new country amongst new competitors, the conditions of its life will generally be changed in an essential manner, although the climate may be exactly the same as in its former home. If its average numbers are to increase in its new home, we should have to modify it in a different way to what we should have had to do in its native country; for we should have to give it some advantage over a different set of competitors or enemies.

It is good thus to try in imagination to give to any one species an advantage over another. Probably in no single instance should we know what to do. This ought to convince us of our ignorance on the mutual relations of all organic beings; a conviction as necessary as it is difficult to acquire. All that we can do is to keep steadily in mind that each organic being is striving to increase in a geometrical ratio; that each at some period of its life, during some season of the year, during each generation or at intervals, has to struggle for life and to suffer great destruction. When we reflect on this struggle, we may console ourselves with the full belief that the war of nature is not incessant, that no fear is felt, that death is generally prompt, and that the vigorous, the healthy, and the happy survive and multiply.

QUESTIONS AND EXERCISES

This chapter from *The Origin of Species* is not only characteristic of the writer in its clear and direct style, but well illustrates the method of Darwin's patient and vigorously scientific cast of mind,—generalization from a large accumulation of data. In his autobiography, Darwin has told how after long years of pondering and puzzling over the discrete mass of material gathered from various sources, his voyage on the "Beagle," his correspondents all over the world, and his own experiments, suddenly there flashed into his mind one day as he was out driving, the great principle of natural selection which unified this vast accumulation of material. Darwin's method of simplifying his mass of facts in this selection may profitably be compared with Spencer's method in the chapter on rhythm.

1. How many examples and illustrations are used in the chapter? Has Darwin employed more than are actually necessary to establish

his thesis? Has he selected for mention the more striking facts? From what sources has he obtained the facts upon which he bases his generalizations? What evidences have you of the carefulness of Darwin's observations? Does he impress you as being a specialist in our narrow modern sense of the word?

2. Is the arrangement of topics clear and logical? Is the order of progression inductive or deductive? Has Darwin employed the most effective order for his purpose?

3. Is Darwin careful to define his terms? Compare him with Huxley or with Spencer in this respect.

4. Note all the summarizing paragraphs in this chapter. Is the very explicit summary at the end of the chapter characteristic of Darwin? Examine the other chapters of the *Origin of Species;* examine also the relation of the last chapter in *Vegetable Mould and Earth-Worms* to the preceding chapters.

5. Are the paragraphs noticeably similar in structure? Analyze a typical paragraph.

6. For what kind of readers does Darwin seem to write? What tone does he adopt toward them?

7. Characterize Darwin's style. In his "Memoirs" he complains more than once of his unfitness for writing, and of the drudgery which it caused him. Does his style seem labored? He also complains of awkwardness in sentence structure. Are any of his sentences in this chapter confused or involved?

Exercise 1. Write upon one of the following subjects taking pains to be clear and methodical: The organization of a bank; the organization of ——— College or University; the organization of ——— Manufacturing Company.

HANDLING A TOPIC INVOLVING PREJUDICE

SCOPE AND LIMIT OF SCIENTIFIC MATERIALISM[1]

JOHN TYNDALL

PARTLY through mathematical and partly through experimental research, physical science has of late years assumed a momentous position in the world. Both in a material and in an intellectual point of view it has produced, and is designed to produce, immense changes—vast social ameliorations, and vast alterations in the popular conception of the origin, rule, and governance of natural things. By science, in the physical world, miracles are wrought, while philosophy is forsaking its ancient metaphysical channels and pursuing others which have been opened or indicated by scientific research. This must become more and more the case as philosophical writers become more deeply imbued with the methods of science, better acquainted with the facts which scientific men have won, and with the great theories which they have elaborated.

If you look at the face of a watch, you see the hour and minute hands, and possibly also a second hand, moving over the graduated dial: Why do these hands move, and why are their relative motions such as they are observed to be? These questions cannot be answered without opening the watch, mastering its various parts, and ascertaining their relationship to each other. When this is done, we find that the observed motion of the hands follows of necessity from the inner mechanism of the watch, when acted upon by the force invested in the spring.

[1] Reprinted from *Fragments of Science*, published by Messrs. D. Appleton & Co.

The motions of the hands may be called a phenomenon of art, but the case is similar with the phenomena of nature. These also have their inner mechanism, and their store of force to set that mechanism going. The ultimate problem of physical science is to reveal this mechanism, to discern this store, and to show that from the combined action of both the phenomena of which they constitute the basis must of necessity flow.

I thought that an attempt to give you even a brief and sketchy illustration of the manner in which scientific thinkers regard this problem would not be uninteresting to you on the present occasion; more especially as it will give me occasion to say a word or two on the tendencies and limits of modern science; to point out the region which men of science claim as their own, and where it is mere waste of time to oppose their advance, and also to define, if possible, the bourne between this and that other region to which the questionings and yearnings of the scientific intellect are directed in vain.

But here your tolerance will be needed. It was the American Emerson, I think, who said that it is hardly possible to state any truth strongly without apparent injustice to some other truth. Truth is often of a dual character, taking the form of a magnet with two poles; and many of the differences which agitate the thinking part of mankind are to be traced to the exclusiveness with which partisan reasoners dwell upon one half of the duality in forgetfulness of the other half. The proper course appears to be to state both halves strongly, and allow each its fair share in the formation of the resultant conviction. But this waiting for the statement of the two sides of the question implies patience. It implies a resolution to suppress indignation if the statement of the one half should clash with our convictions, and to repress equally undue elation if the half-statement should happen to chime in with our views. It implies a determination to wait calmly for the statement of the whole, before we pronounce judgement in the form of either acquiescence or dissent.

This premised, and, I trust, accepted, let us enter upon our

task. There have been writers who affirmed that the pyramids of Egypt were the productions of nature; and in his early youth Alexander von Humboldt wrote a learned essay with the express object of refuting this notion. We now regard the pyramids as the work of men's hands, aided probably by machinery of which no record remains. We picture to ourselves the swarming workers toiling at these vast erections, lifting the inert stones, and guided by the volition, the skill, and possibly at times by the whip of the architect, placing them in their proper positions. The blocks in this case were moved and posited by a power external to themselves, and the final form of the pyramid expresses the thought of its human builder.

Let us pass from this illustration of constructive power to another of a different kind. When a solution of common salt is slowly evaporated, the water which holds the salt in solution disappears, but the salt itself remains behind. At a certain stage of concentration the salt can no longer retain the liquid form ; its particles, or molecules, as they are called, begin to deposit themselves as minute solids, so minute, indeed, as to defy all microscopic power. As evaporation continues solidification goes on, and we finally obtain, through the clustering together of innumerable molecules, a finite crystalline mass of a definite form. What is this form ? It sometimes seems a mimicry of the architecture of Egypt. We have little pyramids built by the salt, terrace above terrace from base to apex, forming a series of steps resembling those up which the Egyptian traveller is dragged by his guides. The human is as little disposed to look unquestioning at these pyramidal salt crystals as to look at the pyramids of Egypt without inquiring whence they came. How, then, are those salt pyramids built up?

Guided by analogy, you may, if you like, suppose that, swarming among the constituent molecules of the salt, there is an invisible population, controlled and coerced by some invisible master, and placing the atomic blocks in their positions. This, however, is not the scientific idea, nor do I think your good sense will accept it as a likely one. The scientific idea is that the molecules act upon each other without the intervention of

slave labor; that they attract each other and repel each other at certain definite points, or poles, and in cetain definite directions; and that the pyramidal form is the result of this play of attraction and repulsion. While, then, the blocks of Egypt were laid down by a power external to themselves, these molecular blocks of salt are self-posited, being fixed in their places by the forces with which they act upon each other.

I take common salt as an illustration because it is so familiar to us all; but any other crystalline substance would answer my purpose equally well. Everywhere, in fact, throughout inorganic nature, we have this formative power, as Fichte would call it—this structural energy ready to come into play and build the ultimate particles of matter into definite shapes. The ice of our winters and of our polar regions is its handywork, and so equally are the quartz, felspar, and mica of our rocks. Our chalk-beds are for the most part composed of minute shells, which are almost the product of structural energy ; but behind the shell, as a whole, lies a more remote and subtle formative act. These shells are built up of little crystals of calc-spar, and to form these crystals the structural force had to deal with the intangible molecules of carbonate of lime. This tendency on the part of matter to organize itself, to grow into shape, to assume definite forms in obedience to the definite action of force, is, as I have said, all-pervading. It is in the ground on which you tread, in the water you drink, in the air you breathe. Incipient life, as it were, manifests itself throughout the whole of what we call inorganic nature.

The forms of the minerals resulting from this play of polar forces are various, and exhibit different degrees of complexity. Men of science avail themselves of all possible means of exploring their molecular architecture. For this purpose they employ in turn as agents of exploration light, heat, magnetism, electricity, and sound. Polarized light is especially useful and powerful here. A beam of such light, when sent in among the molecules of a crystal, is acted on by them, and from this action we infer with more or less of clearness the manner in which the molecules are arranged. That differences, for

example, exist between the inner structure of rock salt and crystallized sugar or sugar-candy, is thus strikingly revealed. These differences may be made to display themselves in chromatic phenomena of great splendor, the play of molecular force being so regulated as to remove some of the colored constituents of white light, and to leave others with increased intensity behind.

And now let us pass from what we are accustomed to regard as a dead mineral to a living grain of corn. When *it* is examined by polarized light, chromatic phenomena similar to those noticed in crystals are observed. And why? Because the architecture of the grain resembles the architecture of the crystal. In the grain also the molecules are set in definite positions, and in accordance with their arrangement they act upon the light. But what has built together the molecules of the corn? I have already said regarding crystalline architecture that you may, if you please, consider the atoms and molecules to be placed in position by a power external to themselves. The same hypothesis is open to you now. But if in the case of crystals you have rejected this notion of an external architect, I think you are bound to reject it now, and to conclude that the molecules of the corn are self-posited by the forces with which they act upon each other. It would be poor philosophy to invoke an external agent in the one case and reject it in the other.

Instead of cutting our grain of corn into slices and subjecting it to the action of polarized light, let us place it in the earth and subject it to a certain degree of warmth. In other words, let the molecules, both of the corn and of the surrounding earth, be kept in that state of agitation which we call warmth. Under these circumstances, the grain and the substances which surround it interact, and a definite molecular architecture is the result. A bud is formed; this bud reaches the surface, where it is exposed to the sun's rays, which are also to be regarded as a kind of vibratory motion. And as the motion of common heat with which the grain and the substances surrounding it were first endowed, enabled the grain and these substances to exercise their attractions and repulsions, and thus to coalesce in

definite forms, so the specific motion of the sun's rays now enables the green bud to feed upon the carbonic acid and the aqueous vapor of the air. The bud appropriates these constituents of both for which it has an elective attraction, and permits the other constituent to resume its place in the air. Thus the architecture is carried on. Forces are active at the root, forces are active in the blade, the matter of the earth and the matter of the atmosphere are drawn towards both, and the plant augments in size. We have in succession the bud, the stalk, the ear, the full corn in the ear; the cycle of molecular action being completed by the production of grains similar to that with which the process began.

Now there is nothing in this process which necessarily eludes the conceptive or imagining power of the purely human mind. An intellect the same in kind as our own would, if only sufficiently expanded, be able to follow the whole process from beginning to end. It would see every molecule placed in its position by the specific attractions and repulsions exerted between it and other molecules, the whole process and its consummation being an instance of the play of molecular force. Given the grain and its environment, the purely human intellect might, if sufficiently expanded, trace out *a priori* every step of the process of growth, and by the application of purely mechanical principles demonstrate that the cycle must end, as it is seen to end, in the reproduction of forms like that with which it began. A similar necessity rules here to that which rules the planets in their circuits round the sun.

You will notice that I am stating my truth strongly, as at the beginning we agreed it should be stated. But I must go still further, and affirm that in the eye of science *the animal body* is just as much a product of molecular force as the stalk and ear of corn, or as the crystal of salt or sugar. Many of the parts of the body are obviously mechanical. Take the human heart, for example, with its system of valves, or take the exquisite mechanism of the eye or hand. Animal heat, moreover, is the same in kind as the heat of a fire, being produced by the same chemical process. Animal motion, too, is as directly derived from the

food of the animal as the motion of Trevethyck's walking engine from the fuel in its furnace. As regards matter, the animal body creates nothing; as regards force, it creates nothing. Which of you by taking thought can add one cubit to his stature? All that has been said, then, regarding the plant may be restated with regard to the animal. Every particle that enters into the composition of a muscle, a nerve, or a bone, has been placed in its position by molecular force. And unless the existence of law in these matters is denied, and the element of caprice introduced, we must conclude that, given the relation of any molecule of the body to its environment, its position in the body might be determined mathematically. Our difficulty is not with the *quality* of the problem, but with its *complexity;* and this difficulty might be met by the simple expansion of the faculties which we now possess. Given this expansion, with the necessary data, and the chick might be deduced as rigorously and as logically from the egg as the existence of Neptune was deduced from the disturbances of Uranus, or as conical refraction was deduced from the undulatory theory of light.

You see I am not mincing matters, but avowing nakedly what many scientific thinkers more or less distinctly believe. The formation of a crystal, a plant, or an animal, is in their eyes a purely mechanical problem, which differs from the problems of ordinary mechanics in the smallness of the masses and the complexity of the processes involved. Here you have one half of our dual truth; let us now glance at the other half. Associated with this wonderful mechanism of the animal body we have phenomena no less certain than those of physics, but between which and the mechanism we discern no necessary connection. A man, for example, can say *I feel, I think, I love;* but how does *consciousness* infuse itself into the problem? The human brain is said to be the organ of thought and feeling; when we are hurt the brain feels it; when we ponder it is the brain that thinks; when our passions or affections are excited it is through the instrumentality of the brain. Let us endeavor to be a little more precise here. I hardly imagine there exists a profound scientific thinker, who has reflected upon the subject,

unwilling to admit the extreme probability of the hypothesis, that for every fact of consciousness, whether in the domain of sense, of thought, or of emotion, a certain definite molecular condition is set up in the brain; who does not hold this relation of physics to consciousness to be invariable, so that, given the state of the brain, the corresponding thought or feeling might be inferred; or given the thought or feeling, the corresponding state of the brain might be inferred.

But how inferred? It is at bottom not a case of logical inference at all, but of empirical association. You may reply that many of the inferences of science are of this character; the inference, for example, that an electric current of a given direction will deflect a magnetic needle in a definite way; but the cases differ in this, that the passage from the current to the needle, if not demonstrable, is thinkable, and that we entertain no doubt as to the final mechanical solution of the problem. But the passage from the physics of the brain to the corresponding facts of consciousness in unthinkable. Granted that a definite thought and a definite molecular action in the brain occur simultaneously; we do not possess the intellectual organ, nor apparently any rudiment of the organ, which would enable us to pass, by a process of reasoning, from the one to the other. They appear together, but we do not know why. Were our minds and senses so expanded, strengthened, and illuminated as to enable us to see and feel the very molecules of the brain; were we capable of following all their motions, all their groupings, all their electric discharges, if such there be; and were we intimately acquainted with the corresponding states of thought and feeling, we should be as far as ever from the solution of the problem, "How are these physical processes connected with the facts of consciousness?" The chasm between the two classes of phenomena would still remain intellectually impassable. Let the consciousness of *love*, for example, be associated with a right-handed spiral motion of the molecules of the brain, and the consciousness of *hate* with a left-handed spiral motion. We should then know when we love that the motion is in one direction, and when we

hate that the motion is in the other; but the "WHY?" would remain as unanswerable as before.

In affirming that the growth of the body is mechanical, and that thought, as exercised by us, has its correlative in the physics of the brain, I think the position of the "Materialist" is stated as far as that position is a tenable one. I think the materialist will be able finally to maintain this position against all attacks; but I do not think, in the present condition of the human mind, that he can pass beyond this position. I do not think he is entitled to say that his molecular groupings and his molecular motions *explain* everything. In reality they explain nothing. The utmost he can affirm is the association of two classes of phenomena, of whose real bond of union he is in absolute ignorance. The problem of the connection of body and soul is as insoluble in its modern form as it was in the pre-scientific ages. Phosphorus is known to enter into the composition of the human brain, and a trenchant German writer has exclaimed, "Ohne Phosphor, kein Gedanke." That may or may not be the case, but even if we knew it to be the case, the knowledge would not lighten our darkness. On both sides of the zone here assigned to the materialist he is equally helpless. If you ask him whence is this "Matter" of which we have been discoursing, who or what divided it into molecules, who or what impressed upon them this necessity of running into organic forms, he has no answer. Science is mute in reply to these questions. But if the materialist is confounded and science rendered dumb, who else is prepared with a solution? To whom has this arm of the Lord been revealed? Let us lower our heads and acknowledge our ignorance, priest and philosopher, one and all. Perhaps the mystery may resolve itself into knowledge at some future day. The process of things upon this earth has been one of amelioration. It is a long way from the Iguanodon and his contemporaries to the President and the Members of the British Association. And whether we regard the improvement from the scientific or from the theological point of view, as the result of progressive development, or as the result of successive exhibitions of creative energy, neither

view entitles us to assume that man's present faculties end the series—that the process of amelioration stops at him. A time may therefore come when this ultra-scientific region by which we are now enfolded may offer itself to terrestrial, if not human investigation. Two-thirds of the rays emitted by the sun fail to arouse in the eye the sense of vision. The rays exist, but the visual organ requisite for their translation into light does not exist. And so from this region of darkness and mystery which surrounds us rays may now be darting which require but the development of the proper intellectual organs to translate them into knowledge as far surpassing ours as ours surpasses that of the wallowing reptiles which once held possession of this planet. Meanwhile the mystery is not without its uses. It certainly may be made a power in the human soul; but it is a power which has feeling, not knowledge, for its base. It may be, and will be, and we hope is turned to account, both in steadying and strengthening the intellect, and in rescuing man from that littleness to which in the struggle for existence or for precedence in the world he is continually prone.

QUESTIONS AND EXERCISES

The skilful handling of a subject on which one is likely to meet opposition on the part of his readers is well illustrated in this piece of Tyndall's. Upon the present subject the writer feels that there is considerable prejudice—feels that he is going contrary to the deeply seated beliefs of many of his hearers. The problem is one of some delicacy: examine carefully Tyndall's method of meeting it.

1. What attitude does the writer take toward his readers? Toward his subject matter?

2. Does he state "both halves" strongly?

3. Show how the succeeding steps in the explanation increase in complexity.

4. The exposition proceeds smoothly enough up to paragraph thirteen. At this point the writer feels that he is getting on doubtful ground—ground on which his readers may be unwilling to follow him. Just what is the nature of the implied hostility? Does the writer make any concessions, or does he keep true to his original purpose?

5. Is the expression (in paragraph thirteen), "the quality of the problem," clear? Express the thought in your own words.

6. In paragraph fifteen the lines of the preceding explanation are brought to a focus. Sum up in a single concise sentence the substance of the explanation thus far presented.

7. "It is at bottom not a case of logical inference at all, but of empirical association." Explain in your own words.

8. "But the passage from the physics of the brain to the corresponding facts of consciousness is unthinkable." Explain in your own words.

9. Examine now the proportion of parts in the piece. Compare the amounts of space given to the two halves of the discussion. Can you justify this distribution?

10. Study Tyndall's use of concrete instances. From what fields of knowledge are his examples drawn? How are his illustrations adapted to his readers? Would his selection of examples have been different had the discussion been meant exclusively for engineers? Why the example of the watch first and that of the human body last? Notice the elements of story in paragraphs five and six. Do these add interest to the explanation? Compare the succeeding illustrations.

11. Examine the paragraphing of the selection. Doubtless the clearness and effectiveness of the selection is very materially aided by the skilful division of the material into paragraphs, and by the careful organization of each particular paragraph. Notice how the paragraph length increases as the explanation proceeds. Account for this.

12. Make a careful study of Tyndall's sentence structure. Are his sentences ever complex and involved? Is this because his thought is comparatively simple? Would the fact that the piece was first delivered as an address account for the character of the sentences? How?

13. Characterize the writer's vocabulary. Do you find any technical terms?

Exercise 1. Write an explanation for readers who are strongly prejudiced in the matter of the doctrine of evolution or of the scientific value of vaccination or vivisection.

Exercise 2. Write an essay upon a college subject not popular, such as the abolition of admission fees for intercollegiate games, or a requirement that Freshmen shall not join fraternities. Try to present your view favorably to your fellow-students, taking pains to present your ideas in a tactful way.

ESTABLISHING A THEORY BY OVERTHROWING OTHERS

THE ORIGIN OF THE YOSEMITE VALLEY[1]

JOSIAH DWIGHT WHITNEY

ALL will recognize in the Yosemite a peculiar and unique type of scenery. Cliffs absolutely vertical, like the upper portions of the Half Dome and El Capitan, and of such immense height as these, are, so far as we know, to be seen nowhere else. The dome form of mountains is exhibited on a grand scale in other parts of the Sierra Nevada; but there is no Half Dome, even among the stupendous precipices at the head of the King's River. No one can avoid asking, What is the origin of this peculiar type of scenery? How has this unique valley been formed, and what are the geological causes which have produced its wonderful cliffs, and all the other features which combine to make this locality so remarkable? These questions we will endeavor to answer, as well as our ability to pry into what went on in the deep-seated regions of the earth, in former geological ages, will permit.

Most of the great cañons and valleys of the Sierra Nevada have resulted from aqueous denudation, and in no part of the world has this kind of work been done on a larger scale. The long-continued action of tremendous torrents of water, rushing with impetuous velocity down the slopes of the mountains, has excavated those immense gorges by which the chain of the Sierra Nevada is furrowed, on its western slope, to the depth of thou-

[1] Reprinted from *The Yosemite Guide-Book*. Acknowledgement for the suggestion of this selection is made to Carpenter and Brewster's *Modern English Prose*.

sands of feet. This erosion, great as it is, has been done within a comparatively recent period, geologically speaking, as is conclusively demonstrated in numerous localities. At the Abbey's Ferry crossing of the Stanislaus, for instance, a portion of the mass of Table Mountain is seen on each side of the river, in such a position as to demonstrate that the current of the lava which forms the summit of this mountain once flowed continuously across what is now a cañon over 2000 feet deep, showing that the erosion of that immense gorge has all been effected since the lava flowed down from the higher portion of the Sierra. This event took place, as we know from the fossil bones and plants embedded under the volcanic mass, at a very recent geological period, or in the latter part of the Tertiary epoch, and after the appearance of man on the earth.

The eroded cañons of the Sierra, however, whose formation is due to the action of water, never have vertical walls, nor do their sides present the peculiar angular forms which are seen in the Yosemite, as, for instance, in El Capitan, where two perpendicular surfaces of smooth granite, more than 3000 feet high, meet each other at a right angle. It is sufficient to look for a moment at the vertical faces of El Capitan and the Bridal Veil Rock, turned down the Valley, or away from the direction in which the eroding forces must have acted, to be able to say that aqueous erosion could not have been the agent employed to do any such work. The squarely cut re-entering angles, like those below El Capitan, and between Cathedral Rock and the Sentinel, or in the Illilouette cañon, were never produced by ordinary erosion. Much less could any such cause be called in to account for the peculiar formation of the Half Dome, the vertical portion of which is all above the ordinary level of the walls of the Valley, rising 2000 feet, in sublime isolation, above any point which could have been reached by denuding agencies, even supposing the current of water to have filled the whole Valley.

Much less can it be supposed that the peculiar form of the Yosemite is due to the erosive action of ice. A more absurd theory was never advanced than that by which it was sought

to ascribe to glaciers the sawing out of these vertical walls, and the rounding of the domes. Nothing more unlike the real work of ice, as exhibited in the Alps, could be found. Besides, there is no reason to suppose, or at least no proof, that glaciers have ever occupied the Valley or any portion of it, as will be explained in the next chapter; so that this theory, based on entire ignorance of the whole subject, may be dropped without wasting any more time upon it.

The theory of erosion not being admissible to account for the formation of the Yosemite Valley, we have to fall back on some one of those movements of the earth's crust to which the primal forms of mountain valleys are due. The forces which have acted to produce valleys are complex in their nature, and it is not easy to classify the forms which have resulted from them in a satisfactory manner. The two principal types of valleys, however, are those produced by rents or fissures in the crust, and those resulting from flexures or foldings of the strata. The former are usually transverse to the mountain chain in which they occur; the latter are more frequently parallel to them, and parallel to the general strike of the strata of which the mountains are made up. Valleys which have originated in cross fractures are usually very narrow defiles, enclosed within steep walls of rocks, the steepness of the walls increasing with the hardness of the rock. It would be difficult to point to a good example of this kind of valley in California; the famous defile of the Via Mala in Switzerland is one of the best which could be cited. Valleys formed by foldings of the strata are very common in many mountain chains, especially in those typical ones, the Jura and the Appalachian. Many of the valleys of the Coast Ranges are of this order. A valley formed in either one of the ways suggested above may be modified afterwards by forces pertaining to either of the others; thus a valley originating in a transverse fissure may afterwards become much modified by an erosive agency, or a longitudinal flexure valley may have one of its sides raised up or let down by a "fault" or line of fissure running through or across it.

If we examine the Yosemite to see if the traces of an origin in

either of the above ways can be detected there, we obtain a negative answer. The Valley is too wide to have been formed by a fissure; it is about as wide as it is deep, and, if it had been originally a simple crack, the walls must have been moved bodily away from each other, carrying the whole chain of the Sierra with them, to one side or the other, or both, for the distance of half a mile. Besides, when a cliff has been thus formed, there will be no difficulty in recognizing the fact, from the correspondence of the outlines of the two sides; just as, when we break a stone in two, the pieces must necessarily admit of being fitted together again. No correspondence of the two sides of the Yosemite can be detected, nor will the most ingenious contriving, or lateral moving, suffice to bring them into anything like adaptation to each other. A square recess on one side is met on the other, not by a corresponding projection, but by a plain wall or even another cavity. These facts are sufficient to make the adoption of the theory of a rent or fissure impossible. There is much the same difficulty in conceiving of the formation of the Valley by any flexure or folding process. The forms and outlines of the masses of rock limiting it are too angular, and have too little development in any one direction; they are cut off squarely at the upper end, where the ascent to the general level of the country is by gigantic steps, and not by a gradual rise. The direction of the Valley, too, is transverse to the general line of elevation of the mountains, and not parallel with it, as it should be, roughly at least, were it the result of folding or upheaval.

In short, we are led irresistibly to the adoption of a theory of the origin of the Yosemite Valley in a way which has hardly yet been recognized as one of those in which valleys may be formed, probably for the reason that there are so few cases in which such an event can be absolutely proved to have occurred. We conceive that, during the process of upheaval of the Sierra, or, possibly, at some time after that had taken place, there was at the Yosemite a subsidence of a limited area, marked by lines of "fault" or fissures crossing each other somewhat nearly at right angles. In other and more simple language, the bottom

of the Valley sank down to an unknown depth, owing to its support being withdrawn from underneath during some of those convulsive movements which must have attended the upheaval of so extensive and elevated a chain, no matter how slow we may imagine the process to have been. Subsidence, over extensive areas, of portions of the earth's crust, is not at all a new idea in geology, and there is nothing in this peculiar application of it which need excite surprise. It is the great amount of vertical displacement for the small area implicated which makes this a peculiar case; but it would not be easy to give any good reason why such an exceptional result should not be brought about, amid the complicated play of forces which the elevation of a great mountain chain must set in motion.

By the adoption of the subsidence theory for the formation of the Yosemite, we are able to get over one difficulty which appears insurmountable with any other. This is the very small amount of *dêbris* at the base of the cliffs, and even, at a few points, its entire absence, as previously noticed in our description of the Valley. We see that fragments of rocks are loosened by rain, frost, gravity, and other natural causes, along the walls, and probably not a winter elapses that some great mass of detritus does not come thundering down from above, adding, as it is easy to see from actual inspection of those slides which have occurred within the past few years, no inconsiderable amount to the *talus*. Several of these great rock-avalanches have taken place since the Valley was inhabited. One which fell near Cathedral Rock is said to have shaken the Valley like an earthquake. This abrasion of the edges of the Valley has unquestionably been going on during a vast period of time; what has become of the detrital material? Some masses of granites now lying in the Valley—one in particular near the base of the Yosemite Fall—are as large as houses. Such masses as these could never have been removed from the Valley by currents of water; in fact, there is no evidence of any considerable amount of aqueous erosion, for the cañon of the Merced below the Yosemite is nearly free from detritus, all the way down to the plain. The falling masses have not been carried out by a

glacier, for there are below the Valley no remains of the moraines which such an operation could not fail to have formed.

It appears to us that there is no way of disposing of the vast mass of detritus, which must have fallen from the walls of the Yosemite since the formation of the Valley, except by assuming that it has gone down to fill the abyss, which was opened by the subsidence which our theory supposes to have taken place. What the depth of the chasm may have been we have no data for computing; but that it must have been very great is proved by the fact that it has been able to receive the accumulation of so long a period of time. The cavity was, undoubtedly, occupied by water, forming a lake of unsurpassed beauty and grandeur, until quite a recent epoch. The gradual desiccation of the whole country, the disappearance of the glaciers, and the filling up of the abyss to nearly a level with the present outlet, where the Valley passes into a cañon of the usual form, have converted the lake into a valley with a river meandering through it. The process of filling up still continues, and the *talus* will accumulate perceptibly fast, although a long time must elapse before the general appearance of the Valley will be much altered by this cause, so stupendous is the vertical height of its walls, and so slow their crumbling away, at least as compared with the historic duration of time.

Lake Tahoe and the valley which it partly occupies we conceive also to be, like the Yosemite, the result of local subsidence. It has evidently not been produced by erosion; its depth below the mountains on each side, amounting to as much as 3000 feet, forbids this idea, as do also its limited area and its parallelism with the axis of the chain. The Lake is still very deep, over 1000 feet; but how deep it was originally, and how much detritus has been carried into it, we have no data for even crudely estimating.

QUESTIONS AND EXERCISES

In this selection we note another step in scientific procedure. The writer is not merely stating a problem or reviewing explanations of a phenomenon, but is on the one hand tearing down what he con-

siders untenable hypotheses, and on the other hand substituting for them what he considers a true one.

1. The opening paragraph is an example of a well-managed introduction. Point out its good qualities.

2. What are the two plausible but untenable theories in regard to the origin of the Yosemite Valley brought forward for consideration?

3. Explain the grounds on which each of these theories is ruled out.

4. The points of attack in such procedure are generally: (1) What in regard to the facts—are they correct? and (2) What as to the interpretation of these facts—are they plausible? Along which of these lines is the attack made in this selection?

5. Outline carefully the structure of these first two stages of the thought.

6. Give the substance of the theory which the writer regards as adequate to explain the phenomenon under discussion. Does it receive a comparatively longer treatment than the discarded theories? Are there any details of it that might with advantage be expanded? Has he given the adopted theory sufficient proof?

Exercise 1. Using the method of the selection just studied, write an essay on one of the following subjects:

Theories concerning the shape of the earth.
Theories concerning the origin of man.
Causes of volcanoes.
The most plausible account of the origin of language.
A theory of the tides.
Theories of the ether.
The nature of electricity.
Treeless prairies—how explained.

EXPLAINING BY THE METHOD OF DESCRIPTION

THE SURFACE OF THE MOON[1]

NATHANIEL SOUTHGATE SHALER

SEEN by persons of ordinarily good vision, even at a distance of about 240,000 miles, the moon reveals much of its surface shape, structure, and color; it is evident that the color varies greatly from very bright areas to those which are relatively dark, that the latter are somewhat less in total extent than the former, and that they are disposed in a general way across the northern hemisphere. Persons of more than usually good vision may, under favorable conditions, see on the edge of the illuminated area the ragged line of the sunlight, which indicates that the surface is very irregular, the high points coming into the day before the lower are illuminated. Such persons at time of full moon can also note, though faintly, some of the bright bands which, radiating from certain crater-like pits, extend for great distances over the surface. So, too, they may see at the first stage of the new and the last of the old moon, the light from the sunlit earth slightly illuminating the dark part of the lunar sphere, or, as it is often termed, the old moon in the arms of the new.

With the best modern telescopes under the most suitable conditions of observation the moon is seen as it would be by the unaided eye if it were not more than about 40 miles from the observer. The conditions of this seeing are much more favorable than those under which we behold a range of terrestrial

[1] Reprinted from *Smithsonian Contributions to Knowledge*, Vol. XXXIV, by permission of the Smithsonian Institution.

mountains at that distance, for the reason that the air, and especially the moisture, in our atmosphere hinders and confuses the light, and there is several times as much of this obstruction encountered in a distance of 40 miles along the earth's surface as there is in looking vertically upward.

Seen with the greater telescopes, the surface of the moon may reveal to able observers, in the rare moments of the best seeing, circular objects, such as pits, which are perhaps not more than 500 feet in diameter. Elevations of much less height may be detected by their shadows, which, because there is no trace of an atmosphere on the moon, are extraordinarily sharp, the line between the dark and light being as distinct as though drawn by a ruler. Elongate objects, such as rifts or crevices in the surface, because of their length, may be visible even when they are only a few score feet in width, for the same reason that while a black dot on a wall may not make any impression on the eye, a line no wider than the dot can be readily perceived. Owing to these conditions, the surface of the moon has revealed many of its features to us, perhaps about as well as we could discern them by the naked eye if the sphere were no more than 20 miles away.

Separated from all theories and prepossessions, the most important points which have been ascertained as to the condition of the moon s surface are as follows:

The surface differs from that of the earth in the fact that it lacks the envelopes of air and water. That there is no air is indicated by the feature above noted—that there is no diffusion of the sunlight, the shadows being absolutely black and with perfectly clean-cut edges. It is also shown by the fact that when a star is occulted or shut out by the disc of the moon it disappears suddenly without its light being displaced, as it would be by refraction if there were any sensible amount of air in the line of its rays. This evidence affords proof that if there is any air at all on the moon's surface it is probably less in amount than remains in the nearest approach to a vacuum we can produce by means of an air pump. Like proof of the airless nature of the moon is afforded by the spectroscope ap-

plied to the study of the light of an occulting star or that of the sun as it is becoming eclipsed by the moon. In act, a great body of evidence goes to show that there is no air whatever on the lunar surface.

The evidence of lack of water at the present time on the surface of the moon appears to be as complete as that which shows the lack of an atmosphere. In the first place, there are evidently no seas or even lakes of discernible size. There are clearly no rivers. If such features existed, the reflection of the sun from their surfaces would make them exceedingly conspicuous on the dark background of the moon, which for all its apparent brightness is really as dark as the more somber-hued rocks of the earth's surface when lit by the sun. Moreover, even were water present, without an atmosphere there could be no such circulation as takes place on the earth, upward to clouds and thence downward by the rain and streams to the ocean. Clouds can not exist unless there be an atmosphere in which they can float, and even if there be an air of exceeding tenuity on the moon, it is surely insufficient to support a trace of clouds. Some distinguished astronomers have thought to discern something floating of a cloud-like nature, but these observations, though exceedingly interesting, are not sufficiently verified to have much weight against the body of well-observed facts that shows the moon to be essentially waterless.

The well-established absence of both air and water in any such quantities as is necessary to maintain organic life appears to exclude the possibility of there being any such life as that of plants and animals on the lunar surface. It may be stated that very few astronomers are now inclined to believe that the moon can possibly be the abode of living forms.

Being without an effective atmosphere, for the possible but unproved remnant that may exist there would be quite ineffective, the moon lacks the defense against radiation of heat which the air affords the earth. Therefore in the long lunar night the outflow of heat must bring the temperature of the darkened part to near that of the celestial spaces, certainly to some hundred degrees below Fahrenheit zero. Even in the

long day this lack of air and consequent easy radiation must prevent any considerable warming of the surface. The temperature of the moon has been made the matter of numerous experiments. These, for various reasons, have not proved very effective. The most trustworthy, the series undertaken by S. P. Langley, indicate that at no time does the heat attain to that of melting ice.

Turning now to the shape and structure of the moon's crust, we observe that it differs much from that of the earth. Considering first the more general features, we note that there are none of those broad ridges and furrows—the continents and the sea basins. A portion of the surface, mainly in the northern hemisphere, is occupied by wide plains, which in their general shape are more nearly level than any equally extensive areas of the land, or, so far as we know, of the ocean floor of the earth, though they are beset with very many slight irregularities. These areas of rough, dark-hued plains are the seas or maria of selenographers, so termed because of old they were, from their relatively level nature, supposed to be areas of water. These maria occupy about one-third of the visible surface. Their height is somewhat less than that of the crust outside of their area. The remaining portion of the moon is extremely rugged. It is evident that the average declivity of the slopes is far greater than on the earth. This is apparent in all the features made visible by the telescope, and it likely extends to others too minute to be seen by the most powerful instruments. Zöllner, by a very ingenious computation based on the amount of sunlight reflected, estimates that the average angle of the lunar surface to its horizon is 52 degrees. Though we have no such basis for reckoning the average slope of the lands and sea bottoms of the earth, it is eminently probable that it does not amount to more than a tenth of that declivity. This difference, as well as many others, is probably due to the lack on the moon of the work of water, which so effectively breaks down the steeps of the earth, tending ever to bring the surface to a uniform level.

The most notable feature on the lunar surface is the existence

of exceedingly numerous pits, generally with ring-like walls about them, which slope very steeply to a central cavity and more gently toward the surrounding country. These pits vary greatly in size; the largest are more than a hundred miles in diameter, while the smallest discernible are less than a half mile across. The number increases as the size diminishes; there are many thousands of them, so small that they are revealed only when sought for with the most powerful telescopes and with the best seeing. In all these pits, except those of the smallest size, and possibly in these also, there is within the ring wall and at a considerable though variable depth below its summit a nearly flat floor, which often has a central pit of small size or in its place a steep, rude cone. When this plain is more than 20 miles in diameter, and with increasing numbers as the floor is wider, there are generally other irregularly scattered pits and cones. Thus in the case of Plato, a ring about 60 miles in diameter, there are some scores of these lesser pits. On the interior of the ring walls of the pits over 10 miles in diameter there are usually more or less distinct terraces, which suggest, if they do not clearly indicate, that the material now forming the solid floors they inclose was once fluid and stood at greater heights in the pit than that at which it became permanently frozen. It is, indeed, tolerably certain that the last movement of this material of the floors was one of interrupted subsidence from an originally greater elevation on the outside of the ring wall, which is commonly of irregular height, with many peaks. There are sometimes tongues or protrusions of the substance which forms the ring, as if it had flowed a short distance and then had cooled with steep slopes.

The foregoing account of the pits on the lunar surface suggests to the reader that these features are volcanoes. That view of their nature was taken by the astronomers who first saw them with the telescope and has been generally held by their successors. That they are in some way, and rather nearly, related to the volcanic vents of the earth appears certain. We have now to note the following peculiar conditions of these pits. First, that they exist in varying proportion, with no evident

law of distribution, all over the visible area of the moon. Next, that in many instances they intersect each other, showing that they were not all formed at the same time, but in succession; that the larger of them are not found on the maria, but on the upland and apparently the older parts of the surface; and that the evidence from the intersections clearly shows that the greater of these structures are prevailingly the elder and that in general the smallest were the latest formed. In other words, whatever was the nature of the action involved in the production of these curious structures, its energy diminished with time, until in the end it could no longer break the crust.

All over the surface of the moon, outside of the maria, in the regions not occupied by the volcano-like structures, we find an exceedingly irregular surface, consisting usually of rude excrescences with no distinct arrangement, which may attain the height of many thousand feet. These, when large, have been termed mountains, though they are very unlike any on the earth in their lack of the features due to erosion, as well as in the general absence of order in their association. Elevations of this steep, lumpy form are common on all parts of the moon. Outside of the maria they are seen at their best in the region near the north pole, where a large field thus beset is termed the Alps. From the largest of these elevations a series of like forms can be made of smaller and smaller size until they become too minute to be revealed by the telescope; as they decrease in height they tend to become more regular in shape, very often taking on a dome-like aspect. The only terrestrial elevations at all resembling these lunar reliefs are certain rarely occurring masses of trachytic lava, which appear to have been spewed out through crevices in a semifluid state, and to have been so rapidly hardened in cooling that the slopes of the solidified rock remained very steep. The only reliefs on the moon that remind the geologist of true mountains are certain low ridges on the surfaces of the maria.

The surface of the moon exhibits a very great number of fissures or rents which, when widely opened, are termed valleys, and when narrow, rills. Both these names were given because

these grooves were supposed to have been the result of erosion due to flowing water. The valleys are frequently broad, in the case of that known as the "Alpine Valley," at certain places several miles in width; they are steep walled, and sometimes a mile or more in depth; their bottoms, when distinctly visible, are seen to be beset with crater-like pits, and show in no instance a trace of water work, which necessarily excavates smooth descending floors such as we find in terrestrial valleys. The rills are narrow crevices, often so narrow that their bottoms can not be seen; they frequently branch, and in some instances are continued as branching cracks for 100 miles or more. The characteristic rills are far more abundant than the valleys, there being many scores already described; the slighter are evidently the more numerous; a catalogue of those visible in the best telescopes would probably amount to several thousand.

It is a noteworthy fact that in the case of the rills, and in great measure also in the valleys, the two sides of the fissure correspond so that if brought together the rent would be closed. This indicates that they are essentially cracks which have opened by their walls drawing apart. Curiously enough, as compared with rents in the earth's crust, there is little trace of a change of level of the two sides of these rills—only in one instance is there such a displacement well made out, that known as the Straight Wall, where one side of the break is several hundred feet above the other.

In the region outside of the maria much of the general surface of the moon between the numerous crater-like openings appears in the best seeing with powerful telescopes to be beset with minute pits, often so close together that their limits are so far confused that it appears as honeycombed, or, rather, as a mass of furnace slag full of holes if greatly magnified, through which the gases developed in melting the mass escaped.

Perhaps the most exceptional feature of the lunar surface, as compared with that of the earth, is found in the numerous systems of radiating light bands, in all about thirty in number, which diverge from patches of the same hue about certain of the crater-like pits. These bands of light-colored material are

generally narrow, not more than a few miles in width; they extend for great distances, certain of them being over 1,000 miles in length, one of them attaining to 1,700 miles in linear extent. In one instance at least, in the crater named Saussure, a band which intersects the pit may be seen crossing its floor, and less distinctly, yet clearly enough, it appears on the steep inside walls of the cavity. In no well-observed case do these radiating streaks of light-colored material coincide with the before-mentioned splits or rifts. Yet the assemblage of facts, though the observations and the theories based upon them are very discrepant, lead us to believe that they are in the nature of stains or sheets of matter on the surface of the sphere, or perhaps in the mass of the crust. At some points the rays of one system cross those of another in a manner that indicates that the one is of later formation than the other.

Perhaps the most puzzling feature of the radiating streaks, where everything is perplexing, is found in the way they come into view and disappear in each lunar period. When the surface is illuminated by the very oblique rays of the sun they are quite invisible; as the lunar day advances they become faintly discernible, but are only seen in perfect clearness near the full moon. The reason for this peculiar appearance of these light bands under a high sun has been a matter of much conjecture; it is the subject of discussion in a later chapter of this memoir, where it is shown that inasmuch as these bands appear when the earth light falls upon the moon at a high angle, the effect must be due to the angle of incidence of the rays on the shining surfaces. It should be noted that the light bands in most instances diverge from more or less broad fields of light color about the crater-like pits, fields which have the same habit of glowing under a high illumination; in fact, a large part of the surface of the moon, perhaps near one-tenth of its visible area, becomes thus relatively brilliant at full moon, though it lacks that quality at the earlier and later stages of the lunar day.

In the above-considered statement concerning the visible phenomena of the moon no account is taken of a great variety of obscure features which, though easily seen with fairly good

instruments, have received slight attention from selenographers. As can readily be imagined, observers find it difficult to discern dimly seen features which can not be classed in any group of terrestrial objects. Whosoever will narrowly inspect any part of the lunar surface, noting everything that meets his eye, will find that he observes much that can not be explained by what is seen on the earth. It is evident, indeed, that while in the earlier stages of development this satellite in good part followed the series of changes undergone by its planet, there came a stage in which it ceased to continue the process of evolution that the parent body has undergone. The reason for this arrest in development appears to have been the essential if not complete absence of an atmosphere and of water.

The difference in height between the lowest and highest points on the lunar surface is not determined. To the most accented reliefs, those of the higher crater walls, elevations of more than 25,000 feet have been assigned; it is, however, to be noted that all these determinations are made from the length of the shadows cast by the eminences, with no effective means of correcting for certain errors incidental to this method. It may be assumed as tolerably certain that a number of these elevations have their summits at least 20,000 feet above their bases, and that a few are yet higher. We do not know how much lower than the ground about these elevations are the lowest parts of the moon. My own observations incline me to the opinion that the difference may well amount to as much as 10,000 feet, so that the total relief of the moon may amount to somewhere between 30,000 and 40,000 feet. That of the earth from the deepest part of the oceans to the highest mountain summits is probably between 55,000 and 60,000 feet; so that notwithstanding the lack of erosion and sedimentation which in the earth continually tends to diminish the difference between the sea-floor and land areas, the surface of the satellite has a much less range of elevation than the planet. If the forces which have built the mountains and continents of the earth had operated without the erosive action of water, there is little doubt that the difference in height between the highest and

lowest parts would now be many times as great as it is on the moon.

QUESTIONS AND EXERCISES

In this selection, Shaler is not attempting to arouse in the minds of his readers a series of images or mental pictures of the moon. He is simply trying to make them understand certain facts in regard to the surface of the moon. Since his purpose is not pictorial, that is, appealing to the senses and the imagination, but analytic, appealing primarily to the intellect, this selection should be regarded as a piece of exposition rather than a piece of description. Exposition and description frequently shade into each other, and a line of demarcation can be drawn satisfactorily only by regarding, as in the present case, the aim of the writer and his resulting method of treating the subject.

1. In this selection should be noted especially the simple, clear and adequate plan. Make an outline of the piece.

2. The transitions from paragraph to paragraph are excellent. Underline all words and phrases which serve as such connectives. Are any paragraphs to be found which are purely transitional?

3. Note the cases where the writer in order to make clear some feature of the moon's surface resorts to a comparison with the earth. What is the value of such a device in making clear an obscure idea? Will such a method be valuable only in proportion to the reader's familiarity with the ideas chosen for the comparison?

Exercise 1. Write an account of some city or town as if for a guide book or geography.

Exercise 2. Write on one of the following subjects. Try to use comparison or analogy as much as possible.

The canals of Mars.
The houses of the cliff-dwellers.
The Elizabethan theatre.

Exercise 3. Write to a friend in some distant place an account of the main features of the town in which you live. Suggestions as to what should be included are to be found in this extract from a letter which the noted Dr. Arnold of Rugby wrote to one of his old pupils then living in Tasmania:—

"Will you describe the general aspect of the country round Hobart's Town? . . . Is your country plain or undulating; are your valleys deep or shallow, curving, or with steep sides and flat bottoms? Are your fields large or small, parted by hedges or stone walls, with

single trees about them, or patches of wood here and there? Are there many scattered houses, and what are they built of—brick, wood or stone? And what are the hills and streams like—ridges, or with waving summits? With plain sides, or indented with combs? Full of springs or dry? And what is their geology? I can better fancy the actors when I have got a lively notion of the scene in which they are acting."

Exercise 4. Imagine that the gymnasium of the college is to be made more suitable to the needs of the students. Describe, as if for the building committee of the trustees, the features of such a gymnasium as you would like to see built.

Exercise 5. Make a comparison of the external features of two different makes of typewriters.

Exercise 6. Prepare a report on a certain neighborhood as a place of residence for a friend who is thinking of moving there. Consider carefully the things to be looked out for in selecting a place of residence.

THE UTILIZATION OF NIAGARA[1]

THOMAS COMMERFORD MARTIN

THE broad idea of the utilization of Niagara is by no means new, for even as early as 1725, while the thick woods of pine and oak were still haunted by the stealthy redskin, a miniature sawmill was set up amid the roaring waters. The first systematic effort to harness Niagara was not made until nearly one hundred and fifty years later, when the present hydraulic canal was dug and the mills were set up which disfigure the banks just below the stately falls. It was long obvious that even an enormous extension of this surface canal system would not answer for the proper utilization of the illimitable energy contained in a vast stream of such lofty fall as that of Niagara.

Niagara is the point at which are discharged, through two

[1] A paper read before the Royal Institution of Great Britain, June, 1896. Reprinted by permission of the author from *Proceedings of the Institution*, Vol. XV, p. 269.

narrowing precipitous channels only 3,800 feet wide and 160 feet high, the contents of 6,000 cubic miles of water, with a reservoir area of 90,000 square miles, draining 300,000 square miles of territory. The ordinary overspill of this Atlantic set on edge has been determined to be equal to about 275,000 cubic feet per second, and the quantity passing is estimated as high as 100,000,000 tons of water per hour.

The drifting of a ship over the Horse Shoe Fall has proved it to have a thickness at the center of the crescent of over 16 feet. Between Lake Erie and Lake Ontario there is a total difference of level of 300 feet, and the amount of power represented by the water at the falls has been estimated on different bases from 6,750,000 horsepower up to not less than 16,800,000 horsepower, the latter being a rough calculation of Sir William Siemens, who, in 1877, was the first to suggest the use of electricity as the modern and feasible agent of converting into useful power some of this majestic but squandered energy.

It may be noted that the water passing out at Niagara is wonderfully pure and "soft," contrasting strongly, therefore, with the other body of water, turbid and gritty, that flows from the north out through the banks of the Mississippi. The annual recession of the American Fall, of 7½ inches, and of the Horse Shoe, of 2.18 feet, would probably have been much greater had the water been less limpid.

The roar of the falls, which can be heard for many miles, has a deep note, four octaves lower than the scale of the ordinary piano. The fall of such an immense body of water causes a very perceptible tremor of the ground throughout the vicinity. The existence of the falls is also indicated by huge clouds of mist which, rising above the rainbows, tower sometimes a mile in air before breaking away.

It was Mr. Thomas Evershed, an American civil engineer, who unfolded the plan of diverting part of the stream at a considerable distance above the falls, so that no natural beauty would be interfered with, while an enormous amount of power would be obtained with a very slight reduction in the volume of the stream at the crest of the falls. Essentially scientific

and correct as the plan now shows itself to be, it found prompt criticism and condemnation, but not less quickly did it rally the able and influential support of Messrs. W. B. Rankine, Francis Lynde Stetson, Edward A. Wickes, and Edward D. Adams, who organized the corporate interests that, with an expenditure of £1,000,000 in five years, have carried out the present work.

So many engineering problems arose early in the enterprise that after the survey of the property in 1890 an International Niagara Commission was established in London, with power to investigate the best existing methods of power development and transmission, and to select from among them, as well as to award prizes of an aggregate of £4,400. This body included men like Lord Kelvin, Mascart, Coleman Sellers, Turrettini, and Dr. Unwin, and its work was of the utmost value. Besides this the Niagara Company and the allied Cataract Construction Company enjoyed the direct aid of other experts, such as Prof. George Forbes, in a consultative capacity; while it was a necessary consequence that the manufacturers of the apparatus to be used threw upon their work the highest inventive and constructive talent at their command.

The time-honored plan in water-power utilization has been to string factories along a canal of considerable length, with but a short tail race. At Niagara the plan now brought under notice is that of a short canal with a very long tail race. The use of electricity for distributing the power allows the factories to be placed away from the canal, and in any location that may appear specially desirable or advantageous.

The perfected and concentrated Evershed scheme comprises a short surface canal 250 feet wide at its mouth, 1¼ miles above the falls, far beyond the outlying Three Sisters Islands, with an intake inclined obliquely to the Niagara River. This canal extends inwardly 1,700 feet, and has an average depth of some 12 feet, thus holding water adequate to the development of about 100,000 horsepower. The mouth of the canal is 600 feet from the shore line proper, and considerable work was necessary in its protection and excavation. The bed is now of clay,

and the side walls are of solid masonry 17 feet high, 8 feet at the base, and 3 feet at the top. The northeastern side of the canal is occupied by a power house, and is pierced by ten inlets guarded by sentinel gates, each being the separate entrance to a wheel pit in the power house, where the water is used and the power is secured. The water as quickly as used is carried off by a tunnel to the Niagara River again.

The massive canal power house is a handsome building, designed by Stanford White, and likely to stand until Niagara, spendthrift fashion, has consumed its way backward, through its own crumbling strata of shale and limestone, to the base of it. This building is outwardly of hard limestone, and inwardly of enamel brick and ordinary brick coated with white enamel paint. It is 200 feet in length at present, and has a 50-ton Sellers electric traveling crane for the placing of machinery and the handling of any parts that need repair. The wheel pit, over which the power house is situated, is a long, deep, cavernous slot at one side, under the floor, cut in the rock, parallel with the canal outside. Here the water gets a fall of about 140 feet before it smites the turbines. The arrangement of the dynamos generating the current up in the power house is such that each of them may be regarded as the screw at the end of a long shaft, just as we might see it if we stood an ocean steamer on its nose with its heel in the air. At the lower end of the dynamo shaft is the turbine in the wheel pit bottom, just as in the case of the steamer shaft we find attached to it the big triple or quadruple expansion marine steam engine. Perhaps we might compare the dynamo and the turbine to two reels, stuck one on each end of a long lead pencil, so that when the lower reel is turned the upper reel must turn also. You might also compare the dynamos to bells up in the old church steeple, and the turbines to the ringers in the porch, playing the chimes and triple bob majors by their work on the long ropes that hang down. The wheel pit which contains the turbines is 178 feet in depth, and connects by a lateral tunnel with the main tunnel running at right angles. This main tunnel is no less than 7,000 feet in length, with an average hydraulic slope of 6 feet in

1,000. It has a maximum height of 21 feet, and a width of 18 feet 10 inches, its net section being 386 square feet. The water rushes through it and out of its mouth of stone and iron at a velocity of 26½ feet per second, or nearly 20 miles an hour.

More than 1,000 men were employed continuously for more than three years in the construction of this tunnel. More than 300,000 tons of rock were removed, which have gone to form part of the new foreshore near the power house. More than 16,000,000 bricks were used for the lining, to say nothing of the cement, concrete, and cut stone. The labor was chiefly Italian. The brick that fences in the headlong torrent consists of four rings of the best hard-burned brick of special shape, making a solid wall 16 inches thick. In some places it is thicker than that. Into this tunnel discharges also by a special subtunnel the used-up water from the water wheels of the Niagara Falls Paper Company. The turbines have to generate 5,000 horsepower each, at a distance of 140 feet underground, and to send it up to the surface. For this purpose the water is brought down to each by the supply pen-stock, made of steel tube, and 7½ feet in diameter. This water impinges upon what is essentially a twin wheel, each receiving part of the stream as it rushes in at the center, the arrangement being such that each wheel is three stories high, part of the water in the upper tier serving as a cushion to sustain the weight of the entire revolving mechanism. These wheels, which have 32 buckets and 36 guides, discharge 430 cubic feet per second, and they make 250 revolutions per minute. At 75 per cent. efficiency they give 5,000 horsepower. The shaft that runs up from each one to the dynamo is of peculiar and interesting construction. It is composed of steel three-fourths inch thick, rolled into tubes which are 38 inches in diameter. At intervals this tube passes through journal bearings or guides that steady it, at which the shaft is narrowed to 11 inches in diameter and solid, flaring out again each side of the journal bearings. The speed gates of the turbine wheels are plain circular rims, which throttle the discharge on the outside of the wheels, and which, with the coöperation of the governors, keep the speed constant within

2 per cent. under ordinary conditions of running. These wheels are of the Swiss design of Faesch and Picard, and have been built by I. P. Morris & Co., of Philadelphia, for this work.

The dynamos thus directly connected to the turbines are of the Tesla two-phase type. Each of these dynamos produces two alternating currents, differing 90 degrees in phase from each other, each current being of 775 ampères and 2,250 volts, the two added together making, in round figures, very nearly 5,000 horsepower. This amount of energy in electrical current is delivered to the circuits for use when the dynamo is run by the turbine at the moderate speed of 250 revolutions per minute, or, say, 4 revolutions per second. Here, then, we have, broadly, a Tesla two-phase system embodying the novel suggestions and useful ideas of many able men, among whom should be specially mentioned Mr. L. B. Stillwell, the engineer of the Westinghouse Electric Company, upon whom the responsibility was thrown for its success.

Each generator, from the bottom of the bedplate to the floor of the bridge above it, is 11 feet 6 inches high. Each generator weighs 170,000 pounds, and the revolving part alone weighs 79,000 pounds. In most dynamos the armature is the revolving part, but in this case it is the field that revolves, while the armature stands still. It is noteworthy that if the armature inside the field were to revolve in the usual manner, instead of the field, its magnetic pull would be added to the centrifugal force in acting to disrupt the revolving mass; but as it is the magnetic attraction toward the armature now acts against the centrifugal force exerted on the field, and thus reduces the strains in the huge ring of spinning metal. The stationary armature inside the field is built up of thin sheets of mild steel. Along the edges of these sheets are 187 rectangular notches to receive the armature winding, in which the current is generated. This winding is in reality not a winding, as it consists of solid copper bars $1\frac{1}{32}$ by $\frac{7}{16}$ inch, and there are two of these bars in every square hole, packed in with mica as a precaution against heating. These copper conductors are bolted and soldered to V-shaped copper connectors, and are then grouped so as to

form two separate independent circuits. A pair of stout insulated cables connect each circuit with the power-house switchboard.

The rotating field magnet outside the armature consists of a huge forged steel ring, made from a solid ingot of fluid compressed steel 54 inches in diameter, which was brought to a forging heat and then expanded upon a mandril, under a 14,000-ton hydraulic press, to the ring, 11 feet $7\frac{1}{8}$ inches in diameter. On the inside of this ring are bolted 12 inwardly projecting pole pieces of mild open-hearth steel, and the winding around each consists of rectangular copper bars incased in 2 brass boxes. Each pole piece, with its bobbin, weighs about $1\frac{1}{4}$ tons, and the speed of this mass of steel, copper, and brass is 9,300 feet, or $1\frac{3}{4}$ miles per minute, when the apparatus is running at its normal 250 revolutions. Not until the ring was speeded up to 800 revolutions, or 6 miles per minute, would it fly asunder under the impulse of centrifugal force. As a matter of fact, 400 revolutions is the highest speed that can be attained. This revolving field magnet is connected with the shaft that has to turn it, and is supported from above by a 6-armed cast-steel spider keyed to the shaft, this spider or driver forming a roof or penthouse over the whole machine. The shaft itself is held in 2 bearings inside the castings, around which the armature is built up, and at the bearings is nearly 13 inches in diameter. At the lower end is a flange fitting with the flange at the top of the turbine shaft, and at the upper end is a taper, over which the driver fits. The driver and shaft have a deep keyway, and into this a long and massive key fits, holding them solidly together. The driver is of mild cast steel, having a tensile strength of 74,700 pounds per square inch. The bushings of the bearings are of bronze, with zigzag grooves, in which oil under pressure is in constant circulation. Grooves are also cut in the hub of each spider to permit the circulation of water to cool the bearings, this water coming direct from the city mains at a pressure of 60 pounds to the square inch. The oil returns to a reservoir, and is used over and over again. Provision has been made against undue heating, and plenty of chance is given for

air to circulate. This is necessary, as about 100 horsepower of current is going into heat, due to the lost magnetization of the iron and the resistance in the conductors themselves. Ventilators or gills in the drivers are so arranged as to draw up air from the base of the machine and eject it at considerable velocity, so that whatever heat is unavoidably engendered is rapidly dissipated.

In almost all electrical plants the switchboard is a tall wall or slab of marble or mahogany, not unlike a big front door with lots of knobs, knockers, and keyholes on it; but at the Niagara power house it takes the form of an imposing platform, or having in mind its controlling functions, we may compare it to the bridge of an ocean steamer, while the man in charge or handling the wheels answers to the navigating officer. The ingenious feature is employed of using compressed air to aid in opening and closing the switches. The air comes from a compressor located at the wheel pit and driven by a small water motor. It supplies air to a large cylindrical reservoir, from which pipes lead to the various switches, the pressure being 125 pounds to the square inch. Another interesting point is that the measuring instruments on the switchboard do not measure the whole current, but simply a derived portion of determined relation to that of the generators. All told, less than a thirtieth of a horsepower gives all the indications required. To the switchboard, current is taken from the dynamos by heavy insulated cable, and it is then taken off by huge copper bus bars which are carefully protected by layers of pure Para gum and vulcanized rubber, two layers of each being used; while outside of all is a special braided covering, treated chemically to render it noncombustible. The calculated losses from heating in a set of four bus bars carrying 25,000 horsepower, or the total output of the first five Niagara generators, is only 10 horsepower. About 1,200 feet of insulated cable have been supplied to carry the current from the dynamos to the switchboard in the power house. It has not broken down until between 45,000 and 48,000 volts of alternating current were applied to it. There are 427 copper wires in that cable, consisting of 61 strands laid up in reverse layers,

each strand consisting of 7 wires. Next to the strand of copper is a wall of rubber one-quarter inch thick, double coated. Over this is wrapped absolutely pure rubber, imported from England and known as cut sheet. Then come two wrappings of vulcanizable Para rubber, next there is a wrapping of cut sheet, and on top of that are two more rubber coats. This is then taped, covered with a substantial braid, and vulcanized. The object in using the cut sheet is to vulcanize it by contact, in order to make it absolutely water tight. This cable weighs just over 4 pounds to the foot, of which 3 pounds are copper and 1 pound insulation.

We have thus advanced far enough to get our current on to the bus bars, and the next step is to get it from them out of the power house. This final work is done by extending our bars, so to speak, and carrying them across the bridge over the canal, into what is known as the transformer house. It is here that the current received from the other side of the canal is to be raised in potential, so that it can be sent great distances over small wires without material loss. Meantime we may note that the Niagara Falls Power Company itself owns more than a square mile around the power house, upon which a large amount of power will be consumed in the near future by manufacturing establishments of all kinds and that it is already delivering power in large blocks electrically for a great variety of purposes. Special apparatus for this work has been built by the General Electric Company. The current for the production of aluminum is made "direct" by passing through static and rotary transformers, while the Acheson carborundum process uses the pure alternating current. Besides this, the trolley road from Niagara to Buffalo is already taking part of its power from the Niagara power house by means of rotary transformers. For these and other local uses the company has constructed subways in which to carry the wire across its own territory. These subways are 5 feet 6 inches high and 3 feet 10 inches wide inside. They are built up with 12 inches of Portland cement and gravel, backed up with about 1 foot of masonry at the bottom and extending about 3 feet up each side.

The electric conductors are carried on insulated brackets or insulators arranged upon the pins along the walls. These brackets are 30 feet apart. At the bottom of the conduit manholes are holes for tapping off into side conduits, and along it all runs a track, upon which an inspector can propel himself on a private trolley car if necessary. Thus is distributed locally the electric power for which the consumer pays the very modest sum of £3 17s. 6d. per electrical horsepower per annum delivered on the wire, or about 2 guineas for a turbine horsepower, a rate which is not be to equaled anywhere, in view of the absolute certainty of the power, free from all annoyance, extra expense, or bother of any kind on the part of the consumer.

It is a curious fact that the proposal to transmit the energy of Niagara long distances over wire should have been regarded with so much doubt and scepticism, and that the courageous backers of the enterprise should have needed time to demonstrate that they were neither knaves nor fools, but simply brave, far-seeing men. We have to-day parallel instances to Niagara in the transmission of oil and natural gas. Oil is delivered in New York City over a line of pipe which is at least 400 miles long, and which has some thirty-five pumping stations en route, the capacity of the line being 30,000 barrels a day. All that oil has first to be gathered from individual wells in the oil region, and delivered to storage tanks with a capacity of 9,000,000 barrels of oil. Chicago, Philadelphia, and Baltimore are centers for similar systems of oil pipe running hundreds of miles over hill and dale. As for natural gas, that is to-day sent in similar manner over distances of 120 miles, Chicago being thus supplied from the Indiana gas fields; and the gas has its pressure raised and lowered several times on its way from the gas well to the consumer's tap, just as though it were current from Niagara.

We must not overlook some of the fantastic schemes proposed for transmitting the power of Niagara before electricity was adopted. One of them was to hitch the turbines to a big steel shaft running through New York State from east to west, so that where the shaft passed a town or factory all you had to do was to hitch on a belt or some gear wheels and thus take off all

the power wanted. Not much less expensive was the plan to have a big tube from New York to Chicago, with Niagara Falls at the center, and with the Niagara turbines hitched to a monster air compressor, which should compress air under 250 pounds pressure to the square inch in the tube.

So far as actual electrical long-distance transmission from Niagara is concerned, it can only be said to be in the embryonic stage, for the sole reason that for nearly a year past the power company has been unable to get into Buffalo, and that not until last year was it able to arrive at acceptable conditions, satisfactory alike to itself and to the city. Work is now being pushed and by June, 1897, power from the falls will, by contract with the city, be in regular delivery to the local consumption circuits at Buffalo, 22 miles away. But the question arises, and has been fiercely discussed, whether it will pay to send the current beyond Buffalo. Recent official investigations have shown that steam power in large bulk, under the most favorable conditions, cost to-day in Buffalo £10 per year per horsepower and upward. Evidently Niagara power, starting at £2 on the turbine shaft or say less than £4 on the line, has a good margin for effective competition with steam in Buffalo.

As to the far-away places, the well-known engineers Prof. E. J. Houston and Mr. A. E. Kennelly have made a most careful estimate of the distance to which the energy of Niagara could be economically transmitted by electricity. Taking established conditions and prices that are asked to-day for apparatus, they have shown, to their own satisfaction at least, that even in Albany or anywhere else in the same radius 330 miles from the falls, the converted energy of the great cataract could be delivered cheaper than good steam engines on the spot could make steam power with coal at the normal price there of 12s. per ton.

What this enterprise at Niagara aims to do is not to monopolize the power but to distribute it, and it makes Niagara, more than it ever was before, common property. After all is said and done, very few people ever see the falls, and then only for a chance holiday once in a lifetime; but now the useful energy of the cataract is made cheaply and immediately available every

day in the year to hundreds and thousands, even millions of people, in an endless variety of ways.

We must not omit from our survey the Erie Canal, in the revival and greater utilization of which as an important highway of commerce Niagara power is expected to play no mean part. In competition with the steam railway, canals have suffered greatly the last fifty years. In the United States, out of 4,468 miles of canal built at a cost of £40,000,000, about one-half has been abandoned and not much of the rest pays expenses. Yet canals have enormous carrying capacity, and a single boat will hold as much as twenty freight cars. The New York State authorities have agreed to conditions by which Niagara energy can be used to propel the canal boats at the rate of £4 per horsepower per year. Where steamboat haulage for 242 tons of freight now costs about 6½d. a boat mile, it is estimated that electric haulage will cost not to exceed 5¼d., while with the energy from Niagara at only £4 per horsepower per year it will cost much less. Some two years ago the first attempt was made in the United States on the Erie Canal with the canal boat *F. W. Hawley*, when the trolley system was used with the motor on the boat as it is on an electric car, driving the propeller as if it were the car wheels. Another plan is that of hauling the boat from the towpath, and that is what is now being done with the electric system of Mr. Richard Lamb on the Erie Canal at Tonawanda, near Niagara. Imagine an elevator shaft working lengthwise instead of vertically. There is placed on poles a heavy fixed cable on which the motor truck rests, and a lighter traction cable is also strung that is taken up and paid out by a sheave as the motor propels itself along and pulls the canal boat to which it is attached. If the boats come from opposite directions they simply exchange motors, just as they might make mules or locomotives, and go on without delay.

On its property at Niagara the power company has already begun the development of the new village called Echota, a pretty Indian name which signifies "place of refuge." I believe it is Mr. W. D. Howells, our American novelist, who in kindred spirit speaks of the "repose" of Niagara. It was laid

out by Mr. John Bogart, formerly State engineer, and is intended to embody all that is best in sanitation, lighting, and urban comfort. It does not need the eye of faith to see here the beginning of one of the busiest, cleanest, prettiest, and healthiest localities in the Union. The workingman whose factory is not poisoned by smoke and dust, whose home was designed by distinguished architects, whose streets and parks were laid out by celebrated engineers, and whose leisure is spent within sight and sound of lovely Niagara, has little cause for grumbling at his lot.

The American company has also preëmpted the great utilization of the Canadian share of Niagara's energy. The plan for this work proposes the erection of two power houses of a total ultimate capacity of 125,000 horsepower. Each power house is fed by its own canal and is therefore an independent unit. Owing to the better lay of the land, the tunnels carrying off the water discharge from the turbines on the Canadian side will have lengths respectively of only 300 and 800 feet, thus avoiding the extreme length and cost unavoidable on the American side. With both the Canadian and American plants fully developed, no less than 350,000 horsepower will be available. The stationary engines now in use in New York State represent only 500,000 horsepower. Yet the 350,000 horsepower are but one-twentieth of the 7,000,000 horsepower which Professor Unwin has estimated the falls to represent theoretically. If the 350,000 horsepower were estimated at £4 per year per horsepower, and should replace the same amount of steam at £10, the annual saving for power in New York State alone would be more than £2,000,000 per year.

Let me, by way of conclusion, emphasize the truth that this splendid engineering work leaves all the genuine beauty of Niagara untouched. It may even help to conserve the scene as it exists to-day, for the terrific weight and rush of waters over the Horseshoe Fall is eating it away and breaking its cliff into a series of receding slopes and rapids; so that even a slight diminution of the whelming mass of wave will to that extent lessen disruption and decay. Be that so or not so, those of us

who are lovers of engineering can now at Niagara gratify that taste in the unpretentious place where some of this vast energy is reclaimed for human use, and then as ever join with those who, not more than ourselves, love natural beauty, and find with them renewed pleasure and delight in the majestic, organ-toned, and eternal cataract.

QUESTIONS AND EXERCISES

This selection serves as a further illustration of the method of description in exposition. The writer is not endeavoring to picture to the imagination the enterprise at Niagara; he is trying to expound it by an appeal to the understanding. Inexactly this piece might be called a "description" of the engineering works at Niagara Falls, but in strict usage it should be called an "exposition."

1. Does this account seem to be accurate and complete? Make a list of all the parts of the engineering work at Niagara that are mentioned.

2. Has the writer striven to make his treatment of the subject interesting, or does he seem to depend upon the reader's supplying this from his interest in the subject?

3. Has the writer apparently endeavored to exclude unessential details?

4. Do you detect any definite order in which the parts of this paper have been arranged?

5. Has he secured emphasis for the more important parts? Is there necessity for prefacing the account of the power house, etc., with the details in the opening paragraphs about the falls? In this connection consider the fact that this paper was written for Englishmen. What possible differences of treatment and selection of material would there have been if it had been intended for an American audience?

Exercise 1. Write an explanatory description of the power-plant that furnishes light for your town; or the pumping station connected with the water system.

Exercise 2. Write a similar account of the system of ventilation used in some public building familiar to you.

Exercise 3. Write an explanatory description of the equipment of some manufacturing plant.

Exercise 4. Write an explanation of how your town obtains its water supply.

Exercise 5. Describe the arrangement of an athletic field.

Exercise 6. Write a description of a modern Weather Bureau office.

Exercise 7. Write a description of a telephone switch board.

THE LOWLAND COTTAGE.—ITALY[1]

"Most musical, most melancholy."

John Ruskin

Let it not be thought that we are unnecessarily detaining our readers from the proposed subject, if we premise a few remarks on the character of the landscape of the country we have now entered. It will always be necessary to obtain some definite knowledge of the distinctive features of a country, before we can form a just estimate of the beauties or the errors of its architecture. We wish our readers to imbue themselves as far as may be with the spirit of the clime which we are now entering; to cast away all general ideas; to look only for unison of feeling, and to pronounce everything wrong which is contrary to the *humours* of nature. We must make them feel where they are; we must throw a peculiar light and color over their imaginations; then we will bring their judgment into play, for then it will be capable of just operation.

We have passed, it must be observed (in leaving England and France for Italy), from comfort to desolation; from excitement to sadness: we have left one country prosperous in its prime, and another frivolous in its age, for one in its glorious death.

Now, we have prefixed the hackneyed line of Il Penseroso to our paper, because it is a definition of the essence of the beautiful. What is most musical will always be found most melancholy; and no real beauty can be obtained without a touch of sadness. Whenever the beautiful loses its melancholy, it

[1] Reprinted from *The Poetry of Architecture.*

degenerates into prettiness. We appeal to the memories of all our observing readers, whether they have treasured up any scene, pretending to be more than pretty, which has not about it either a tinge of melancholy or a sense of danger: the one constitutes the beautiful, the other the sublime.

This postulate being granted, as we are sure it will by most (and we beg to assure those who are refractory or argumentative, that, were this a treatise on the sublime and beautiful, we could convince and quell their incredulity to their entire satisfaction by innumerable instances), we proceed to remark here, once for all, that the principal glory of the Italian landscape is its extreme melancholy. It is fitting that it should be so: the dead are the nations of Italy; her name and her strength are dwelling with the pale nations underneath the earth; the chief and chosen boast of her utmost pride is the *hic jacet;* she is but one wide sepulchre, and all her present life is like a shadow or a memory. And, therefore, or, rather, by a most beautiful coincidence, her national tree is the cypress; and whoever has marked the peculiar character which these noble shadowy spires can give to her landscape, lifting their majestic troops of waving darkness from beside the fallen column, or out of the midst of the silence of the shadowed temple and worshipless shrine, seen far and wide over the blue of the faint plain, without loving the dark trees for their sympathy with the sadness of Italy's sweet cemetery shore, is one who profanes her soil with his footsteps. Every part of the landscape is in unison; the same glory of mourning is thrown over the whole; the deep blue of the heavens is mingled with that of the everlasting hills, or melted away into the silence of the sapphire sea; the pale cities, temple and tower, lie gleaming along the champaign; but how calmly! no hum of men; no motion of multitude in the midst of them; they are voiceless as the city of ashes. The transparent air is gentle among the blossoms of the orange and the dim leaves of the olive; and the small fountains, which, in any other land, would spring merrily along, sparkling and singing among tinkling pebbles, here flow calmly and silently into some pale font of marble, all beautiful with life, worked by some unknown hand,

long ago nerveless, and fall and pass on among wan flowers, and scented copse, through cool leaf-lighted caves or grey Egerian grottos, to join the Tiber or Eridanus, to swell the waves of Nemi, or the Larian Lake. The most minute objects (leaf, flower, and stone), while they add to the beauty, seem to share in the sadness of the whole.

But, if one principal character of Italian landscape is melancholy, another is elevation. We have no simple rusticity of scene, no cowslip and buttercup humility of seclusion. Tall mulberry trees, with festoons of the luxuriant vine, purple with ponderous clusters, trailed and trellised between and over them, shade the wide fields of stately Indian corn; luxuriance of lofty vegetation (catalpa, and aloe, and olive), ranging itself in lines of massy light along the wan champaign, guides the eye away to the unfailing wall of mountain, Alp or Apennine no cold long range of shivery grey, but dazzling light of snow, or undulating breadth of blue, fainter and darker in infinite variety; peak, precipice, and promontory passing away into the wooded hills, each with its tower or white village sloping into the plain; castellated battlements cresting their undulations; some wide majestic river gliding along the champaign, the bridge on its breast and the city on its shores; the whole canopied with cloudless azure, basking in mistless sunshine, breathing the silence of odoriferous air. Now comes the question. In a country of this pomp of natural glory, tempered with melancholy memory of departed pride, what are we to wish for, what are we naturally to expect, in the character of her most humble edifices; those which are most connected with present life, least with the past? What are we to consider fitting or beautiful in her cottage?

We do not expect it to be comfortable, when everything around it betokens decay and desolation in the works of man. We do not wish it to be neat, where nature is most beautiful because neglected. But we naturally look for an elevation of character, a richness of design or form, which, while the building is kept a cottage, may yet give it a peculiar air of cottage aristocracy; a beauty (no matter how dilapidated) which may appear to have been once fitted for the surrounding splen-

dour of scene and climate. Now, let us fancy an Italian cottage before us. The reader who has travelled in Italy will find little difficulty in recalling one to his memory, with its broad lines of light and shadow, and its strange, but not unpleasing mixture of grandeur and desolation. Let us examine its details, enumerate its architectural peculiarities, and see how far it agrees with our preconceived idea of what the cottage ought to be.

The first remarkable point of the building is the roof. It generally consists of tiles of very deep curvature, which rib it into distinct vertical lines, giving it a far more agreeable surface than that of our flatter tiling. The *form* of the roof, however, is always excessively flat, so as never to let it intrude upon the eye; and the consequence is, that, while an English village, seen at a distance, appears all red roof, the Italian is all white wall; and, therefore, though always bright, is never gaudy. We have in these roofs an excellent example of what should always be kept in mind, that everything will be found beautiful, which climate or situation render useful. The strong and constant heat of the Italian sun would be intolerable if admitted at the windows; and, therefore, the edges of the roof project far over the walls, and throw long shadows downwards, so as to keep the upper windows constantly cool. These long oblique shadows on the white surface are always delightful, and are alone sufficient to give the building character. They are peculiar to the buildings of Spain and Italy; for owing to the general darker color of those of more northerly climates, the shadows of their roofs, however far thrown, do not tell distinctly, and render them, not varied, but gloomy. Another ornamental use of these shadows is, that they break the line of junction of the wall with the roof: a point always desirable, and in every kind of building, whether we have to do with lead, slate, tile, or thatch, one of extreme difficulty. This object is farther forwarded in the Italian cottage, by putting two or three windows up under the very eaves themselves, which is also done for coolness, so that their tops are formed by the roof; and the wall has the appearance of having been terminated by large battlements, and roofed over. And, finally, the eaves are seldom kept long on the same

level: double or treble rows of tiling are introduced; long sticks and irregular woodwork are occasionally attached to them, to assist the festoons of the vines; and the graceful irregularity and marked character of the whole must be dwelt on with equal delight by the eye of the poet, the artist, or the unprejudiced architect. All, however, is exceedingly humble; we have not yet met with the elevation of character we expected. We shall find it, however, as we proceed.

The next point of interest is the window. The modern Italian is completely owl-like in his habits. All the day time, he lies idle and inert; but during the night he is all activity: but it is mere activity of inoccupation. Idleness, partly induced by the temperature of the climate, and partly consequent on the decaying prosperity of the nation, leaves indications of its influence on all his undertakings. He prefers patching up a ruin to building a house; he raises shops and hovels, the abodes of inactive, vegetating, brutish poverty, under the protection of the aged and ruined, yet stalwart, arches of the Roman amphitheatre; and the habitations of the lower orders frequently present traces of ornament and stability of material evidently belonging to the remains of a prouder edifice. This is the case sometimes to such a degree as, in another country, would be disagreeable from its impropriety; but, in Italy, it corresponds with the general prominence of the features of a past age, and is always beautiful. Thus, the eye rests with delight on the broken mouldings of the windows, and the sculptured capitals of the corner columns, contrasted, as they are, the one with the glassless blackness within, the other with the ragged and dirty confusion of drapery around. The Italian window, in general, is a mere hole in the thick wall, always well proportioned; occasionally arched at the top, sometimes with the addition of a little rich ornament; seldom, if ever, having any casement or glass, but filled up with any bit of striped or colored cloth, which may have the slightest chance of deceiving the distant observer into the belief that it is a legitimate blind. This keeps off the sun, and allows a free circulation of air, which is the great object. When it is absent, the window becomes a mere black hole, having much the same

relation to a glazed window that the hollow of a skull has to a bright eye; not unexpressive, but frowning and ghastly, and giving a disagreeable impression of utter emptiness and desolation within. Yet there is character in them: the black dots tell agreeably on the walls at a distance, and have no disagreeable sparkling to disturb the repose of surrounding scenery. Besides, the temperature renders everything agreeable to the eye, which gives it an idea of ventilation. A few roughly constructed balconies, projecting from detached windows, usually break the uniformity of the wall. In some Italian cottages there are wooden galleries, resembling those so frequently seen in Switzerland; but this is not a very general character, except in the mountain valleys of North Italy, although sometimes a passage is effected from one projecting portion of a house to another by means of an exterior gallery. These are very delightful objects; and, when shaded by luxuriant vines, which is frequently the case, impart a great gracefulness to the building otherwise unattainable.

The next striking point is the arcade at the base of the building. This is general in cities; and, though frequently wanting to the cottage, is present often enough to render it an important feature. In fact, the Italian cottage is usually found in groups. Isolated buildings are rare; and the arcade affords an agreeable, if not necessary shade in passing from one building to another. It is a still more unfailing feature of the Swiss city, where it is useful in deep snow. But the supports of the arches in Switzerland are generally square masses of wall, varying in size, separating the arches by irregular intervals, and sustained by broad and massy buttresses; while, in Italy, the arches generally rest on legitimate columns, varying in height from one and a half to four diameters, with huge capitals, not unfrequently rich in detail. These give great gracefulness to the buildings in groups: they will be spoken of more at large when we are treating of arrangement and situation.

The square tower, rising over the roof of the farther cottage, will not escape observation. It has been allowed to remain, not because such elevated buildings ever belong to mere cottages, but, first, that the truth of the scene might not be destroyed; and

secondly, because it is impossible, or nearly so, to obtain a group of buildings of any sort, in Italy, without one or more such objects rising behind them, beautifully contributing to destroy the monotony, and contrast with the horizontal lines of the flat roofs and square walls. We think it right, therefore, to give the cottage the relief and contrast which, in reality, it possessed, even though we are at present speaking of it in the abstract.

Having now reviewed the distinctive parts of the Italian cottage in detail, we shall proceed to direct our attention to points of general character. 1. Simplicity of form. The roof, being flat, allows of no projecting garret windows, no fantastic gable ends: the walls themselves are equally flat; no bow-windows or sculptured oriels, such as we meet with perpetually in Germany, France or the Netherlands, vary their white fronts. Now, this simplicity is, perhaps, the principal attribute by which the Italian cottage attains the elevation of character we desired and expected. All that is fantastic in form, or frivolous in detail, annihilates the aristocratic air of a building: it at once destroys its sublimity and size, besides awakening, as is almost always the case, associations of a mean and low character. The moment we see a gable roof, we think of cocklofts; the instant we observe a projecting window, of attics and tent-bedsteads. Now the Italian cottage assumes, with the simplicity, *l'air noble* of buildings of a higher order; and, though it avoids all ridiculous miniature mimicry of the palace, it discards the humbler attributes of the cottage. The ornament it assumes is dignified: no grinning faces, or unmeaning notched planks, but well-proportioned arches, or tastefully sculptured columns. While there is nothing about it unsuited to the humility of its inhabitant, there is a general dignity in its air, which harmonises beautifully with the nobility of the neighbouring edifices, or the glory of the surrounding scenery.

2. Brightness of effect. There are no weather stains on the wall; there is no dampness in air or earth, by which they could be induced; the heat of the sun scorches away all lichens, and mosses, and mouldy vegetation. No thatch or stone crop on the roof unites the building with surrounding vegetation; all

is clear, and warm, and sharp on the eye; the more distant the building, the more generally bright it becomes, till the distant village sparkles out of the orange copse, or the cypress grove, with so much distinctness as might be thought in some degree objectionable. But it must be remembered that the prevailing colour of Italian landscape is blue; sky, hills, water, are equally azure: the olive, which forms a great proportion of the vegetation, is not green, but grey; the cypress, and its varieties, dark and neutral, and the laurel and myrtle far from bright. Now, white, which is intolerable with green, is agreeable contrasted with blue; and to this cause it must be ascribed that the white of the Italian building is not found startling or disagreeable in the landscape. That it is not, we believe, will be generally allowed.

3. Elegance of feeling. We never can prevent ourselves from imagining that we preceive, in the graceful negligence of the Italian cottage, the evidence of a taste among the lower orders refined by the glory of their land, and the beauty of its remains. We have always had strong faith in the influence of climate on the mind, and feel strongly tempted to discuss the subject at length; but our paper has already exceeded its proposed limits, and we must content ourselves with remarking what will not, we think, be disputed, that the eye, by constantly resting either on natural scenery of noble tone and character, or on the architectural remains of classical beauty, must contract a habit of feeling correctly and tastefully; the influence of which, we think, is seen in the style of edifices the most modern and the most humble.

Lastly, Dilapidation. We have just used the term "graceful negligence:" whether it be graceful, or not, is a matter of taste; but the uncomfortable and ruinous disorder and dilapidation of the Italian cottage is one of observation. The splendour of the climate requires nothing more than shade from the sun, and occasionally shelter from a violent storm: the outer arcade affords them both: it becomes the nightly lounge and daily dormitory of its inhabitant, and the interior is abandoned to filth and decay. Indolence watches the tooth of Time with careless eye and nerveless hand. Religion, or its abuse, reduces every

individual of the population to utter inactivity three days out of the seven; and the habits formed in the three regulate the four. Abject poverty takes away the power, while brutish sloth weakens the will; and the filthy habits of the Italian prevent him from suffering from the state to which he is reduced. The shattered roofs, the dark, confused, ragged windows, the obscure chambers, the tattered and dirty draperies, altogether present a picture which, seen too near, is sometimes revolting to the eye, always melancholy to the mind. Yet even this many would not wish to be otherwise. The prosperity of nations, as of individuals, is cold, and hard-hearted, and forgetful. The dead die, indeed, trampled down by the crowd of the living; the place thereof shall know them no more, for that place is not in the hearts of the survivors for whose interest they have made way. But adversity and ruin point to the sepulchre, and it is not trodden on; to the chronicle, and it doth not decay. Who would substitute the rush of a new nation, the struggle of an awakening power, for the dreamy sleep of Italy's desolation, for her sweet silence of melancholy thought, her twilight time of everlasting memories?

Such, we think, are the principal distinctive attributes of the Italian cottage. Let it not be thought that we are wasting time in the contemplation of its beauties; even though they are of a kind which the architect can never imitate, because he has no command over time, and no choice of situation; and which he ought not to imitate, if he could, because they are only locally desirable or admirable. Our object, let it always be remembered, is not the attainment of architectural data, but the formation of taste.

QUESTIONS AND EXERCISES

This selection further illustrates the connection between exposition and description. Ruskin is concerned not with a description of a single Italian cottage, but with a statement of the features characteristic of such dwellings, the features common to the whole class of objects. Such an account of a class of objects, as distinct from a single object, is called *generalized description*, and is clearly a form of exposition.

1. How much of this selection is devoted to details about the Italian cottage? How much of it is interpretative? What changes in the way of omissions and additions would have to be made if the writer's sole purpose were to give you a clear picture?

2. Are the details set down haphazard, or are they carefully arranged? Make an outline of the selection.

3. Does Ruskin incline to the use of specific or general words in this piece? Point out some other features of the diction of this selection.

Exercise 1. Write a generalized description on one cf the following subjects:

A bank.
A college student's room.
A country store.
A rodman's duties.
The village loafer.
The philanthropist.
The trained nurse.
The football man.
The captain of industry.
The early explorer.
The student of to-day.

Exercise 2. Write a generalized account of one of the following:

A lathe.
A colonial house.
A hospital.
The steam shovel.
The Roman house.
An apartment house.
Ancient Greek theatres.
The thermostat.
An incubator.

THE HERRING[1]

Thomas Henry Huxley

If any one wants to exemplify the meaning of the word "fish," he can not choose a better animal than a herring. The body, tapering to each end, is covered with thin, flexible scales, which are very easily rubbed off. The taper head, with its underhung jaw, is smooth and scaleless on the top; the large eye is partly covered by two folds of transparent skin, like eyelids—only immovable and with the slit between them vertical instead of horizontal; the cleft behind the gill-cover is very wide, and, when the cover is raised, the large red gills which lie beneath it are freely exposed. The rounded back bears the single moderately long dorsal fin about its middle. The tail-fin is deeply cleft, and on careful inspection small scales are seen to be continued from the body, on to both its upper and its lower lobes, but there is no longitudinal scaly fold on either of these. The belly comes to an edge, covered by a series of sharply-keeled bony shields between the throat and the vent; and behind the last is the anal fin, which is of the same length as the dorsal fin. There is a pair of fore-limbs, or pectoral fins, just behind the head; and a pair of hind-limbs, or ventral fins, are situated beneath the dorsal fin, a little behind a vertical line drawn from its front edge, and a long way in front of the vent. These fins have bony supports or rays, all of which are soft and jointed.

Like most fishes, the herring is propelled chiefly by the sculling action of the tail-fin, the rest serving chiefly to preserve the balance of the body, and to keep it from turning over, as it would do if left to itself, the back being the heaviest part of the fish.

The mouth of the herring is not very large, the gape extending back only to beneath the middle of the eye, and the teeth on the upper and lower jaws are so small as to be hardly visible.

[1] Extract from a lecture delivered at the National Fishery Exhibition, Norwich, England, 1881. Reprinted from *Popular Science Monthly*, Vol. XIX, p. 433.

Moreover, when a live herring opens its mouth, or when the lower jaw of a dead herring is depressed artificially, the upper jaw, instead of remaining fixed and stationary, travels downward and forward in such a manner as to guard the sides of the gape. This movement is the result of a curious mechanical arrangement by which the lower jaw pulls upon the upper, and I suspect that it is useful in guarding the sides of the gape when the fish gulps the small living prey upon which it feeds.

The only conspicuous teeth, and they are very small, are disposed in an elongated patch upon the tongue, and in another such patch, opposite to these, on the fore part of the roof of the mouth. The latter are attached to a bone called the vomer, and are hence termed vomerine teeth. But, if the mouth of a herring is opened widely, there will be seen, on each side, a great number of fine, long, bristle-like processes, the pointed ends of which project forward. These are what are termed the gill-rakers, inasmuch as they are fixed, like the teeth of a rake, to the inner sides of those arches of bone on the outer sides of which the gills are fixed. The sides of the throat of a herring, in fact, are, as it were, cut by four deep and wide clefts, which are separated by these gill arches, and the water which the fish constantly gulps in by the mouth flows through these clefts, over the gills and out beneath the gill-covers, aërating the blood, and thus effecting respiration, as it goes. But, since it would be highly inconvenient, and indeed injurious, were the food to slip out in the same way, these gill-rakers play the part of a fine sieve, which lets the water strain off, while it keeps the food in. The gill-rakers of the front arches are much longer than those of the hinder arches, and, as each is stiffened by a thread of bone developed in its interior, while, at the same time, its sides are beset with fine sharp teeth, like thorns on a brier, I suspect that they play some part in crushing the life out of the small animals on which the herrings prey.

Between these arches there is, in the middle line, an opening which leads into the gullet. This passes back into a curious conical sac which is commonly termed the stomach, but which has more the character of a crop. Coming off from the under

side of the sac and communicating with it by a narrow opening, there is an elongated tubular organ, the walls of which are so thick and muscular that it might almost be compared to a gizzard. It is directed forward, and opens by a narrow prominent aperture into the intestine, which runs straight back to the vent. Attached to the commencement of the intestine there is a score or more of larger and shorter tubular organs, which are called the pyloric cæca. These open into the intestine, and their apertures may be seen on one side of it, occupying an oval space, in the middle of which they are arranged three in a row.

The chief food of the herring consists of minute crustacea, some of them allied to the shrimps and prawns, but the majority belonging to the same division as the common *Cyclops* of our fresh waters. These tenant many parts of the ocean in such prodigious masses that the water is discolored by them for miles together, and every sweep of a fine net brings up its tens of thousands.

Everybody must have noticed the silvery air-bladder of the herring, which lies immediately under the backbone, and stretches from close to the head to very near the vent, being wide in the middle and tapering off to each end. In its natural state, it is distended with air; and, if it is pricked, the elastic wall shrinks and drives the air out, as if it were an India-rubber ball. When the connections of this air-bladder are fully explored, it turns out to be one of the most curious parts of the organization of the whole animal.

In the first place, the pointed end of the sac or crop into which the gullet is continued runs back into a very slender duct which turns upward and eventually opens into the middle of the air-bladder. The canal of this duct is so very small and irregularly twisted, that, even if the air-bladder is squeezed, the air does not escape into the sac. But, if air is forced into the sac by means of a blowpipe, the air passes without much difficulty the other way, and the air-bladder becomes fully distended. When the pressure is removed, however, the air-bladder diminishes in size to a certain extent, showing that the air escapes somewhere. And, if the blowing up of the air-bladder

is performed while the fish is under water, a fine stream of air-bubbles may be seen to escape close to the vent. Careful anatomical investigation, in fact, shows that the air-bladder does not really end at the point where its silvery coat finishes, but that a delicate tube is continued thence to the left side of the vent, and there ends by an opening of its own.

Now, the air-bladder of all fishes is, to begin with, an outgrowth from the front part of the alimentary canal, and there are a great many fishes in which, as in the herring, it remains throughout life in permanent communication with the gullet. But it is rare to find the duct so far back as in the herring; and, at present, I am not aware that the air-bladder opens externally in any fishes except the herring and a few of its allies.

There is a general agreement among fishermen that herrings sometimes make a squeaking noise when they are first taken out of the water. I have never heard this sound myself, but there is so much concurrent testimony to the fact that I do not doubt it; and it occurs to me that it may be produced, when the herrings are quickly brought up from some depth, by means of this arrangement. For under these circumstances the air which the air-bladder contains expands to such a degree, on being relieved from the pressure of the water, that deep-sea fishes with a closed air-bladder which are brought to the surface rapidly are sometimes fairly turned inside out by the immense distention, or even bursting, of the air-bladder. If the same thing should happen to the herring, the like misfortune would not befall it, for the air would be forced out of the opening in question, and might readily enough produce the squeak which is reported. The common loach is said to produce a piping sound by expelling the air which this fish takes into its intestine for respiratory purposes.

At the opposite end of the air-bladder there is an even more curious arrangement. The silvery coat of the air-bladder ends in front just behind the head. But the air-bladder itself does not terminate here. Two very fine canals, each of which is not more than a two-hundredth of an inch in diameter, though it is surrounded by a relatively thick wall of cartilage, pass forward,

one on each side, from the air-bladder to the back of the skull. The canals enter the walls of the skull, and then each divides into two branches. Finally, each of these two dilates into a bag which lies in a spheroidal chamber of corresponding size and form; and, in consequence of the air which they contain, these bags may be seen readily enough shining through the side-walls of the skull, the bone of which has a peculiar structure where it surrounds them. Now, these two bags, which constitute the termination of the air-bladder on each side, are in close relation with the organ of hearing. Indeed, a process of that organ projects into the front chamber of each side, and is separated by only a very delicate partition from the terminal sac of the air-bladder. Any vibrations of the air in these sacs, or any change in the pressure of the air in them, must thus tell upon the hearing apparatus.

There is no doubt about the existence of these structures, which, together with the posterior opening of the air-bladder, were most accurately described, more than sixty years ago, by the eminent anatomist Weber; but I am afraid we are not much wiser regarding their meaning than we were when they were first made known. In fishes in general, there can be little doubt that the chief use of the air-bladder is to diminish the specific gravity of the fish, and, by rendering its body of nearly the same weight as so much water, to render the business of swimming easier. In those fishes in which the passage of communication between the air-bladder and the alimentary canal is closed, the air is no doubt secreted into the air-bladder by its vessels, which are often very abundant. In the herring the vessels of the air-bladder are very scanty; and it seems probable that the air is swallowed and forced into the air-bladder just as the loach swallows air and drives it into its intestine. And, as I have already suggested, it may be that the narrow posterior canal which leads from the air-bladder to the exterior is a sort of safety-valve allowing the air to escape, when the fish, rapidly ascending or descending, alters the pressure of the water upon the contained air.

This hypothesis may be put forward with some show of prob-

ability, but I really find it difficult to suggest anything with respect to the physiological meaning of the connection between the air-bladder and the ear. Nevertheless such an elaborate apparatus must have some physiological importance; and this conclusion is strengthened by the well-known fact that there are a great many fishes in which the air-bladder and the ear become connected in one way or another. In the carp tribe, for example, the front end of the air bladder is connected by a series of little bones with the organ of hearing, which is, as it were, prolonged backward to meet these bones in the hinder end of the skull. But here the air-bladder, which is very large, may act as a resonator; while in the herring the extreme narrowness of the passages which connect the air-bladder with the ear renders it difficult to suppose that the organ can have any such function.

In addition to the singular connection of the ear with the exterior by the roundabout way of the air-bladder, there are membranous spaces in the walls of the skull by which vibrations can more directly reach the herring's ear. And there is no doubt that the fish is very sensitive to such vibrations. In a dark night, when the water is phosphorescent or, as the fishermen say, there is plenty of "merefire," it is a curious spectacle to watch the effect of sharply tapping the side of the boat as it passes over a shoal. The herrings scatter in all directions, leaving streaks of light behind them, like shooting-stars.

The herring, like other fishes, breathes by means of its gills—the essential part of which consists of the delicate, highly vascular filaments which are set in a double row on the outer faces of each of the gill-arches. The venous blood, which returns from all parts of the body to be collected in the heart, is pumped thence into the gills, and there exchanges its excess of carbonic-acid gas for the gaseous oxygen which is dissolved in sea-water. The freedom of passage of the water and the great size and delicacy of the gills facilitate respiration when the fish is in its native element; but the same peculiarities permitting of the rapid drying and coherence of the gills, and thus bringing on speedy suffocation, render its tenure of life, after removal from the water, as

short as that of any fish. It may be observed, in passing, that the wide clefts behind the gill-covers of the herring have some practical importance, as the fish, thrusting its head through the meshes of the drift-net, is caught behind them, and can not extricate itself. In the herring, the upper end of the last gill-cleft is not developed into a sac or pouch, such as we shall find in some of its near neighbors.

The only other organs of the herring which need be mentioned at present are the milt and roe, found in the male and female herring respectively.

These are elongated organs attached beneath the air-bladder, which lie, one on each side of the abdominal cavity, and open behind the vent by an aperture common to the two. The spermatic fluid of the male is developed in the milt and the eggs of the female in the roe. These eggs, when fully formed, measure from one sixteenth to one twenty-fifth of an inch in diameter; and as, in the ripe female, the two roes or ovaries stretch from one end of the abdominal cavity to the other, occupying all the space left by the other organs, and distending the cavity, the number of eggs which they contain must be very great. Probably 10,000 is an under-estimate of the number of ripe eggs shed in spawning by a moderate-sized female herring. But I think it is safer than the 30,000 of some estimates, which appear to me to be made in forgetfulness of the very simple anatomical considerations that the roe consists of an extensive vascular framework as well as of eggs; and, moreover, that a vast number of the eggs which it contains remain immature, and are not shed at the time of the spawning.

In this brief account of the structure of the herring I have touched only on those points which are peculiarly interesting, or which bear upon what I shall have to say by-and-by. An exhaustive study of the fish from this point of view alone would require a whole course of lectures to itself.

QUESTIONS AND EXERCISES

As we have seen in the case of the two preceding selections a good deal of what is inexactly called description is really exposition. When

the writer makes it his concern to give not the facts merely but the ideas behind the facts, he writes exposition. This selection from Huxley further illustrates exposition by the method of description.

1. Are the details given distinctive of an individual object or are they common to the class to which the object belongs? How much of the selection is devoted to giving details; how much to explanation of these?

2. Could a reasonably accurate drawing be made of a herring from this description? Are more details needed for accuracy? Would more details tend to confuse the reader?

3. Indicate the method of arranging details. Is it an order well suited to the lecturer's occasion and purpose?

4. Is the lecture well proportioned? Why so much space given to the account of the air-bladder?

5. Is the account interesting? Point out some of the devices that enhance interest?

Exercise 1. In a fashion similar to the above selection write an account of a natural object complex in structure, like some animal or vegetable form. Decide upon a simple and natural arrangement for the details, for example, from general aspect to details, from outside inside. The following list is suggestive of topics:

The frog.
The bird (or some particular species, like the woodpecker).
The crayfish.
The grasshopper.
The oyster.
The catfish.
The black bass.
The mosquito.
The honey bee.
Indian corn.
The mushroom.
Orchids.
Some species of tree, as the pine, silver maple, etc.
The plant cell.
A sand dune region.

THE ELECTRIC BURGLAR-ALARM[1]

Elaborate as are the ordinary agencies for the protection of property, they afford but a partial security. Well-lighted streets, careful watchmen, numerous policemen, and strong and ingeniously arranged bolts and bars, are certainly obstacles not easily overcome. But, in his quest of other men's riches, the accomplished burglar has not found them insurmountable. However extensive and vigilant a police force, it can not have all points under its surveillance at once, and this gives the burglar the opportunity which he rarely fails to improve. Bolts and bars are, doubtless, good things in their way; but the experienced cracksman has a cunning beyond them. In the contest between him and the locksmith, the victory has not always been with the latter, though he has produced that marvel of skill and workmanship—the modern safe-lock. The burglar's tools are not such as are thwarted by nice mechanical combinations. Explosives and the simple mechanical powers in his hands have a wonderful range of utility, and are able to frequently set at naught the most elaborate contrivances. The protection afforded by these combined agencies is, however, only realizable to its full extent in the business centers of large cities. In residence districts, and in suburban and country situations where policemen are often few and far between, reliance has chiefly to be placed upon fastenings; and these often prove insufficient. Yet it is especially important for the owner of property that his protection be good, for recovery is very difficult. The advantages are so largely with the thieves, that they can frequently make the search a long and costly, and often a fruitless one. The cost is, in fact, the main bar to recovery. Only when stolen property is of large value does it pay to regain it. Small amounts, such as are usually taken from private houses, are practically irrecoverable.

No practical extension of the ordinary agencies can greatly increase present security. Bars and bolts have now approached very closely to their limit of strength and ingenuity, and police

[1] Reprinted from *Popular Science Monthly*, Vol. XVIII, p. 56.

surveillance is as extensive and perhaps as effective as circumstances will permit. Greater protection must be sought in some further agency—one that will reproduce as nearly as possible the condition of watchfulness present in the daytime. This the electric burglar-alarm is designed to do, and does with a good degree of success. In its earlier forms there were many defects, but in a development of twenty years these have been mostly corrected. It has now attained a simplicity of construction and a certainty of action that make it one of the most useful and trustworthy of man's servitors. Though widely known and appreciated both in this country and abroad, there are probably many not acquainted with it, to whom a brief description will not be without value.

However the details of construction may differ, the essential elements of every system are: a bell to give the alarm, an annunciator to indicate the point from which it proceeds, wires from all the openings of a building, and a battery to furnish the current. The elements are combined in various ways, depending upon the special circumstances of the particular case, but the manner of use is practically the same.

The main piece of apparatus, remarkable alike for the simplicity of its construction and the range of its performance, is the annunciator. In the earlier forms of the alarm the indications were made by means of a simple switchboard provided with buttons bearing the names of the apartments protected. When an alarm sounded, the depression of each of these buttons in turn, until the bell ceased ringing, was necessary to determine its locality. This is still quite largely used, as it is cheaper than the more perfect annunciator, which tells at a glance where the disturbance in the circuit is. In shape and size this latter instrument resembles an ordinary mantel-clock. The indications are given by devices on the face, which vary with different makers. In one form they are made by arrows, which lie horizontal when in normal position, and point to the names of the apartments printed above them when indicating. In another form, cards drop down in front of apertures arranged in rows on the face and in still another the name and number of a room are

Fig. I.

uncovered by a falling piece when an alarm is sounded. The needle-instrument is shown in Fig. 1. Once made, the indications remain until the parts are restored by some one. A small switch at one side completes or opens the circuit through the instrument, and one on the other side controls the connection with the bell. A row of studs at the base of the apparatus allows any opening to be disconnected that may be desired. Aside from its giving an alarm when an attempt is made to enter a building, the annunciator has an important use in showing whether a place is properly closed. If any window or door has been forgotten, it will infallibly point it out. In large business houses where there are many openings, this feature is of the greatest value. By disconnecting the bell, this test can be made a silent one.

The mechanism operating the indicators is of the simplest description. In the needle-instrument, an arm on the pivot of the needle is held in position by the hooked end of a lever, the other end of which forms the armature of an electro-magnet. The connection between the lever and the supported arm is very slight, so that a small movement of the former allows the latter to fall. When the circuit is closed this takes place. The armature in moving toward the magnet raises the hook end of the lever, releasing the arm which drops and turns its needle. In the instrument using the card, the card is carried on the end of an arm held up in a similar manner by a hook on the armature of the magnet. The depression of the armature allows the arm to drop by its weight. The restoring of the arms to position is done by a sliding frame raised by a handle or button on the base of the instrument. Delicate as the movements of the apparatus are, it is not easily put out of order. The points of contact of the hook and arm are so made as to reduce the wear to a minimum. The mechanism is all inclosed, and the exposed parts, such as the needles, switch-handles, etc., finished in polished metal. The annunciator and bell are usually combined into one piece of apparatus, but they may be put up separate when desired.

This secures the proper resetting of the apparatus in readi-

ness for a new alarm. The result is obtained very simply by making the clapper turn a switch, which cuts from the circuit the open window or door, and allows the current to pass directly from the battery to the bell.

The door and window attachments for closing the circuit by the movements of these parts are of various forms. Those used on doors are simply little push-pins placed in the casing. The pin slides in an insulated case provided with metallic strips. When it is pressed in, the contact between it and the strips is broken and the circuit opened. When the pressure is released, the pin springs out, closing the circuit. The slightest movement of a door allows this motion of the pin to take place. In one form the pin and a metallic strip are so arranged that the attempt to keep the pin pushed in, when the door is opened, by inserting a knife-blade, establishes the circuit and gives the alarm. These push-buttons may be constructed to close the circuit, either by pushing in or springing out, and in both forms have a great variety of uses. They may be placed under the carpet, in the hall, on the stairs, in front of a window, or wherever any one entering would be liable to step. A sufficient number properly disposed could make intrusion without giving alarm simply impossible. The window attachments are usually simple springs placed in the casing so that the movement of the sash presses them together. One form consists of a roller on the end of a spring arm, which keeps it pressed out from contact with a metal strip, through which the circuit is completed. Placed in the casing, the roller stands out and is received in a pocket in the edge of the sash, so that the motion of the sash brings the roller arm and metal strip into contact. For the purpose of ventilation the pocket in the upper sash is usually elongated to give a free movement through any desired distance. When the lower sash is left open, security can be gained by covering a push-pin in the window-sill with a flower pot or other obstruction, the removal of which is necessary to gain entrance. The wires forming the circuit are of insulated copper, carefully put up so as to be completely hidden from view. They are run in grooves in the wood-work, carried beneath a floor, or on its

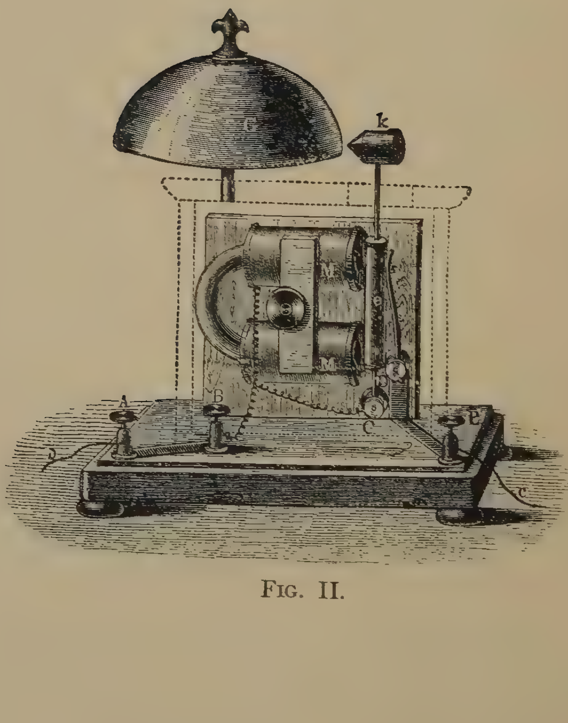


FIG. II.

face according to circumstances. Once in place, they remain unchanged for any period, causing neither trouble nor expense.

The Le Clanché battery is the one universally employed with this apparatus. It is very simple in construction, exhales no noxious gases when in operation, does not waste the material when no current is passing, and needs but very little attention. The positive pole is a piece of gas carbon placed in a porous cell filled with coarse-grained peroxide of manganese and carbon. The cell is sealed at the top with pitch, and a lead cap on the carbon receives the wire. The negative pole is formed with a rod of amalgamated zinc. Both poles are immersed in a solution of sal-ammoniac contained in a glass jar. Four of these elements put up in a wooden case constitute the battery usually furnished.

The bell used is that common with different forms of electrical instruments. It consists of a gong and a clapper vibrated by the combined action of an electro-magnet and spring. The magnet, when the current passes, draws the clapper to itself and in doing so opens the circuit; this destroys its magnetism and allows the spring to carry the clapper back. This "make" and "break" action, rapidly repeated as long as the current is passing, produces a continuous ringing of the bell. Reference to Fig. 2 will make this movement clear. One end of the wire of the coils of the magnet M M is secured to the binding-post B, and the other to the post C. The arm of the clapper *k* is a rather stiff spring, which in its normal position holds the armature *e* carried by it from the poles of the magnet. It then presses against the spring *r*, attached to the post D. The post A and E holding the wires from the battery are respectively connected with B and D by metallic strips. The current enters at A, traverses the coils of the magnet M M, passes through the armature *e*, and out by way of spring *r* and posts D and E. In doing so, the soft-iron cores of the magnet are magnetized and attract the armature *e*. This in moving breaks its contact with the spring *r*, and interrupts the current. The clapper then springs back into position. In the bell now generally used the ringing continues not only while the door or window is open, but until the indicating parts of the annunciator are restored to position.

These appliances provided, the most common way of using the system is to make it complete in each building, the alarm apparatus being placed in a sleeping apartment in a private house, and in the watchman's room in a place of business. So arranged, the condition of the circuit is this: In the daytime, when the doors and windows are open, the circuit is continuous at all points except at the alarm apparatus. At night this is reversed, the circuit being closed at the instrument, and broken at all the points protected. A movement at any of these points which closes the circuit gives the alarm and turns the proper needle in the annunciator. The connection with the alarm is made at night by an attendant, and broken at any desired time in the morning. In private houses fitted with electric bells, a clock is often provided that disconnects the alarm in the morning and turns the current on to a bell placed in the servants' rooms. The movement by which this is done is something similar to that of the ordinary alarm clock.

The protection afforded by such apparatus in good working order is probably as perfect as it can be made. It is generally impossible to cut the wires from the outside of the building, and unless this is done intrusion will start the alarm. Even if the wires be cut, buttons under the carpet or circuit-closers in interior doors will reveal the burglar's presence in perhaps every case.

Valuable as is the protection in any particular case of attempted robbery, the general immunity from such attempts that the presence of the apparatus secures is of still greater moment. Burglars will not generally take such risks as those imposed by an efficient alarm system, and will therefore give a house so protected a wide berth. The only case in which there is room for failure of the system is when the battery power is not sufficient to operate the alarm. But it is a very simple matter to provide against this. Tests once every month or two, and the experience soon gained in using the battery, will enable one to know at any time the state of the system. None of the other parts need ever cause any solicitude.

While in the great majority of cases the plan of giving the alarm to some one in the building broken into affords perfect

security, in some it does not. In business centers, determined and cunning burglars, accustomed to take large chances, might frequently overpower the watchman and stop the alarm before it excited outside attention. To meet this difficulty the plan is sometimes adopted of making the alarm sound in a central office of the company furnishing the apparatus. One company doing this has adopted a system that seems to be beyond circumvention. Each building protected is connected on a closed circuit with the central office, at which place delicate galvanometers are used as indicators. The circuit of each building is independent of all others. Any change in the resistance of any circuit is instantly shown by the deflection of the proper needle, and an alarm started. The opening of a protected door or window breaks the circuit, as does the cutting of the line, and of course gives an alarm. If the burglar could carry the wire to the ground and insert just the proper resistance, no signal would be given at the company's office, but this is impossible, as the resistance is not only that of the wire but of the apparatus in circuit. The only way to get around it is to tunnel under the building, but even then circuit-breakers judiciously disposed would generally lead to detection. Nothing is gained, so far as the safe is concerned, in this case, as it is independently protected. It is placed in a light wooden cabinet lined with a metallic casing, consisting of two sheets of tin-foil insulated from each other by a thin sheet of non-conducting material. The wires from a battery are connected each with one of the sheets of foil. So delicate is the insulation that the sticking of a pin in the cabinet closes the circuit and deflects the needle, and sounds the alarm in the central office. This system, though not yet in extensive use, is gaining in favor among merchants having valuable stores of goods. A similar plan of protecting private houses whose occupants are away is practiced to some extent. The apparatus used in this case is much less delicate, and the protection therefore not so good.

The cost of applying the burglar-alarm to any house will vary in each case. It depends upon the size of the annunciator required and the number of openings to be protected. The prices

charged by the different American manufacturers differ very little. Annunciators range in price from thirty dollars with four indications to one hundred dollars with twenty. The annunciator used should have as many indications as there are rooms protected. The cost of circuit-closers, including the placing in position and laying the wire, is three dollars a window when both sashes are connected. The same devices for doors vary from one and a half to two and a half dollars. In ordinary city houses it is only necessary to connect the windows and doors, front and back, of the first two stories and the opening in the roof. The entire cost will not generally exceed one hundred dollars. In the country the cost would of course be somewhat greater, in the average house probably between a hundred and fifty and two hundred dollars. The apparatus once in, the only expense is the maintenance of the battery. This will generally be very small, probably not more than a dollar a year. Considering the security gained, the outlay required is not excessive, and builders find that is fully made up to them in increased rents. It is not improbable that the apparatus will eventually be considered as necessary to the complete equipment of a house as now are water- and gas-pipes.

QUESTIONS AND EXERCISES

This selection illustrates the method of generalized description applied to a piece of mechanism.

1. How much space is given to a description of the parts of the burglar-alarm? How much to an explanation of the combinations and uses of these parts? Does the writer separate these two parts of the explanation or does he mingle them?

2. What evidence is there to show that the writer is not writing of some particular variety of the burglar-alarm but of those features characteristic of the whole class? Has he noted important modifications of these features to be found in some makes of the alarm?

3. Of what value are the illustrations as aids to clearness?

4. Have there been any important recent improvements in the burglar-alarm?

Exercise 1. Explain in a simple and clear fashion the operation of one of the contrivances in the list below. Let the explanation be

concerned not with some particular variety of the object, but with the essentials of all similar objects of that class. Give such preliminary description of parts as may be necessary for clearness. Diagrams may be used if desired. Then give an explanation of the combination and uses of these parts, or of the principle upon which the combination is based.

The telephone.
The miner's safety lamp.
The electric bell.
The wireless telegraph.
The cash register.
Some piece of laboratory apparatus.
The arc light.
The stereopticon.
The typewriter.
The aeroplane.
A mail-catcher.
The cream separator.
The phonograph.
The Yale lock.
The railway switch.
The compound microscope.

Exercise 2. Explain the construction and operation of one of the following:

The steam engine.
The six-cylinder gas engine.
The steam turbine.
The street-car motor.
The dynamo.

EXPLAINING BY THE METHOD OF NARRATIVE

STORY OF A SALMON[1]

David Starr Jordan

In the realm of the Northwest Wind, on the boundary-line between the dark fir-forests and the sunny plains, there stands a mountain,—a great white cone two miles and a half in perpendicular height. On its lower mile, the dense fir-woods cover it with never-changing green; on its next half-mile, a lighter green of grass and bushes gives place in winter to white; and, on its uppermost mile, the snows of the great Ice age still linger in unspotted purity. The people of Washington Territory say that this mountain is the great "King-pin of the Universe," which shows that, even in its own country, Mount Rainier is not without honor.

Flowing down from the southwest slope of Mount Rainier is a cold, clear river fed by the melting snows of the mountain. Madly it hastens down over white cascades and beds of shining sands, through birch-woods and belts of dark firs to mingle its waters at last with those of the great Columbia.

This river is the Cowlitz, and on its bottom, not many years ago, there lay half-buried in the sand a number of little orange-colored globules, each about as large as a pea. These were not much in themselves, but, like the philosopher's monads, each one had in it the promise and potency of an active life. In the water above them, little suckers and chubs and prickly sculpins were straining their mouths to draw these globules from the

[1] Reprinted by permission of the author from *Popular Science Monthly*, Vol. XIX, p. 1.

sand, and vicious-looking crawfishes picked them up with their blundering hands and examined them with their telescopic eyes. But one, at least, of the globules escaped their scientific curiosity, else this story would not be worth telling.

The sun shone down on it through the clear water, and the ripples of the Cowlitz said over it their incantations, and in it at last awoke a living being. It was a fish, a curious little fellow, only half an inch long, with great, staring eyes which made almost half his length, and a body so transparent that he could not cast a shadow. He was a little salmon, a very little salmon, but the water was good, and there were flies, and worms, and little living creatures in abundance for him to eat, and he soon became a larger salmon. And there were many more little salmon with him, some larger and some smaller, and they all had a merry time. Those who had been born soonest and had grown largest used to chase the others around and bite off their tails, or, still better, take them by the heads and swallow them whole, for, said they, "Even young salmon are good eating." "Heads I win, tails you lose" was their motto. Thus, what was once two small salmon became united into one larger one, and the process of "addition, division, and silence," still went on.

By-and-by, when all the salmon were too small to swallow the others, and too large to be swallowed, they began to grow restless and to sigh for a change. They saw that the water rushing by seemed to be in a great hurry to get somewhere, and one of them suggested that its hurry was caused by something good to eat at the other end of its course. Then they all started down the stream, salmon-fashion, which fashion is to get into the current, head up-stream, and so to drift backward as the river sweeps along.

Down the Cowlitz River they went for a day and a night, finding much to interest them which we need not know. At last, they began to grow hungry, and, coming near the shore, they saw an angle-worm of rare size and beauty floating in an eddy of the stream. Quick as thought one of the boys opened his mouth, which was well filled with teeth of different sizes, and

put it around that angle-worm. Quicker still he felt a sharp pain in his gills, followed by a smothering sensation, and in an instant his comrades saw him rise straight into the air. This was nothing new to them, for they often leaped out of the water in their games of hide-and-seek, but only to come down again with a loud splash not far from where they went out. But this one never came back, and the others went on their course wondering.

At last they came to where the Cowlitz and the Columbia join, and they were almost lost for a time, for they could find no shores, and the bottom and the top of the water were so far apart. Here they saw other and far larger salmon in the deepest part of the current, turning neither to the right nor left, but swimming straight on up just as rapidly as they could. And these great salmon would not stop for them, and would not lie and float with the current. They had no time to talk, even in the simple sign-language by which fishes express their ideas, and no time to eat. They had an important work before them, and the time was short. So they went on up the river, keeping their great purposes to themselves, and our little salmon and his friends from the Cowlitz drifted down the stream.

By-and-by the water began to change. It grew denser, and no longer flowed rapidly along, and twice a day it used to turn about and flow the other way. And the shores disappeared, and the water began to have a different and peculiar flavor—a flavor which seemed to the salmon much richer and more inspiring than the glacier-water of their native Cowlitz. And there were many curious things to see; crabs with hard shells and savage faces, but so good when crushed and swallowed! Then there were luscious squid swimming about, and, to a salmon, squid are like ripe peaches and cream for dinner. There were great companies of delicate sardines and herring, green and silvery, and it was such fun to chase them and to capture them!

Those who eat only sardines, packed in oil by greasy fingers, and herrings dried in the smoke, can have little idea how satisfying it is to have one's stomach full of them, plump and sleek, and silvery, fresh from the sea.

Thus they chased the herrings about and had a merry time. Then they were chased about in turn by great sea-lions, swimming monsters with huge half-human faces, long thin whiskers, and blundering ways. The sea-lions liked to bite out the throats of the salmon, with their precious stomachs full of luscious sardines, and then to leave the rest of the fish to shift for itself.

And the seals and the herrings scattered the salmon about, and at last the hero of our story found himself quite alone, with none of his own kind near him. But that did not trouble him much, and he went on his own way, getting his dinner when he was hungry, which was all the time, and then eating a little between meals for his stomach's sake.

So it went on for three long years; and at the end of this time our little fish had grown to be a great, fine salmon, of forty pounds' weight, shining and silvery as a new tin pan, and with rows of the loveliest round black spots on his head, and back, and tail. One day, as he was swimming about, idly chasing a big sculpin, with a head so thorny that he never was swallowed by anybody, all of a sudden the salmon noticed a change in the water around him.

Spring had come again, and the south-lying snow-drifts on the Cascade Mountains once more felt that the "earth was wheeling sunward," and the cold snow-waters ran down from the mountains and into the Columbia River, and made a freshet on the river, and the high water went far out into the sea, and out in the sea our salmon felt it on his gills; and he remembered how the cold water used to feel in the Cowlitz when he was a little fish, and in a blundering, fishy fashion he thought about it, and wondered whether the little eddy looked as it used to, and whether caddice-worms and young mosquitoes were really as sweet and tender as he used to think they were; and he thought some other things, but, as a salmon's mind is located in the optic lobes of his brain, and ours in a different place, we can not be certain, after all, what his thoughts really were. What he did we know. He did what every grown salmon in the ocean does when he feels the glacier-water once more upon his gills. He

became a changed being. He spurned the blandishments of soft-shelled crabs. The pleasures of the table and of the chase, heretofore his only delights, lost their charms for him. He turned his course straight toward the direction whence the cold fresh water came, and for the rest of his life he never tasted a mouthful of food. He moved on toward the river-mouth, at first playfully, as though he were not really certain whether he meant anything, after all. Afterward, when he struck the full current of the Columbia, he plunged straight forward with an unflinching determination that had in it something of the heroic. When he had passed the rough water at the bar, he found that he was not alone; his old neighbors of the Cowlitz and many more, a great army of salmon, were with him. In front were thousands; pressing on, and behind them, were thousands more, all moved by a common impulse, which urged them up the Columbia.

They were swimming bravely along where the current was deepest, when suddenly the foremost felt something tickling like a cobweb about their noses and under their chins. They changed their course a little to brush it of, and it touched their fins as well. Then they tried to slip down with the current, and thus to leave it behind. But no—the thing, whatever it was, although its touch was soft, refused to let go, and held them like a fetter; and, the more they struggled, the tighter became its grasp. And the whole foremost rank of the salmon felt it together, for it was a great gill-net, a quarter of a mile long, and stretched squarely across the mouth of the river. By-and-by men came in boats and hauled up the gill-net and threw the helpless salmon into a pile on the bottom of the boat, and the others saw them no more. We that live outside the water know better what befalls them, and we can tell the story which the salmon could not.

All along the banks of the Columbia River, from its mouth to nearly thirty miles away, there is a succession of large buildings, looking like great barns or warehouses, built on piles in the river, and high enough to be out of the reach of floods. There are thirty of these buildings, and they are called canneries. Each cannery has about forty boats, and with each boat are two men

and a long gill-net, and these nets fill the whole river as with a nest of cobwebs from April to July; and to each cannery nearly a thousand great salmon are brought in every day. These salmon are thrown in a pile on the floor; and Wing Hop, the big Chinaman, takes them one after another on the table, and with a great knife dexterously cuts off the head, the tail, and the fins; then with a sudden thrust removes the intestines and the eggs. The body goes into a tank of water, and the head goes down the river to be made into salmon-oil. Next, the body is brought on another table, and Quong Sang, with a machine like a feed-cutter, cuts it into pieces just as long as a one-pound can. Then Ah Sam, with a butcher-knife, cuts these pieces into strips just as wide as the can. Then Wan Lee, the China boy, brings down from the loft, where the tinners are making them, a hundred cans, and into each can puts a spoonful of salt. It takes just six salmon to fill a hundred cans. Then twenty Chinamen put the pieces of meat into the cans, fitting in little strips to make them exactly full. Then ten more solder up the cans, and ten more put the cans in boiling water till the meat is thoroughly cooked, and five more punch a little hole in the head of each can to let out the air. Then they solder them up again, and little girls paste on them bright-colored labels showing merry little Cupids riding the happy salmon up to the cannery-door, with Mount Rainier and Cape Disappointment in the background; and a legend underneath says that this is "Booth's" or "Badollet's Best," or "Hume's" or "Clark's," or "Kinney's Superfine Salt-water Salmon." Then the cans are placed in cases, forty-eight in a case, and five hundred thousand cases are put up every year. Great ships come to Astoria and are loaded with them, and they carry them away to London, and San Francisco, and Liverpool, and New York, and Sydney, and Valparaiso, and Skowhegan, Maine; and the man at the corner grocery sells them at twenty cents a can.

All this time our salmon is going up the river, escaping one net as by a miracle, and soon having need of more miracles to escape the rest; passing by Astoria on a fortunate day, which was Sunday, the day on which no man may fish if he expects to sell what

he catches, till finally he came to where nets were few, and, at last, to where they ceased altogether. But here he found that scarcely any of his many companions were with him, for the nets cease when there are no more salmon to be caught in them. So he went on day and night where the water was deepest, stopping not to feed or loiter on the way, till at last he came to a wild gorge, where the great river became an angry torrent rushing wildly over a huge staircase of rocks. But our hero did not falter, and, summoning all his forces, he plunged into the Cascades. The current caught him and dashed him against the rocks. A whole row of silvery scales came off and glistened in the water like sparks of fire, and a place on his side became black and red, which, for a salmon, is the same as being black and blue for other people. His comrades tried to go up with him; and one lost his eye, one his tail, and one had his lower jaw pushed back into his head like the joints of a telescope. Again he tried to surmount the Cascades, and at last he succeeded, and an Indian on the rocks above was waiting to receive him. But the Indian with his spear was less skillful than he was wont to be, and our hero escaped, losing only a part of one of his fins, and with him came one other, and henceforth these two pursued their journey together.

Now a gradual change took place in the looks of our salmon. In the sea he was plump and round and silvery, with delicate teeth, and as handsome and symmetrical a mouth as any one need wish to kiss. Now his silvery color disappeared, his skin grew slimy, and the scales sank into it; his back grew black and his sides turned red—not a healthy red, but a sort of hectic flush. He grew poor, and his back, formerly as straight as need be, now developed an unpleasant hump at the shoulders. His eyes—like those of all enthusiasts who forsake eating and sleeping for some loftier aim—became dark and sunken. His symmetrical jaws grew longer and longer, and, meeting each other, as the nose of an old man meets his chin, each had to turn aside to let the other pass. And his beautiful teeth grew longer and longer, and projected from his mouth, giving him a savage and wolfish appearance, quite unlike his real disposition. For all

the desires and ambitions of his nature had become centered into one. We do not know what this one was, but we know that it was a strong one, for it had led him on and on, past the nets and horrors of Astoria, past the dangerous Cascades, past the spears of the Indians, through the terrible flume of the Dalles, where the mighty river is compressed between huge rocks into a channel narrower than a village street; on past the meadows of Umatilla and the wheat-fields of Walla Walla; on to where the great Snake River and the Columbia join; on up the Snake River and its eastern branch, till at last he reached the foot of the Bitter-Root Mountains in the Territory of Idaho, nearly a thousand miles from the ocean, which he had left in April. With him still was the other salmon which had come with him through the Cascades, handsomer and smaller than he, and, like him, growing poor and ragged and tired. At last, one October afternoon, they came together to a little clear brook, with a bottom of fine gravel, over which the water was but a few inches deep. Our fish painfully worked his way to it, for his tail was all frayed out, his muscles were sore, and his skin covered with unsightly blotches. But his sunken eyes saw a ripple in the stream, and under it a bed of little pebbles and sand. So there in the sand he scooped out with his tail a smooth, round place, and his companion came and filled it with orange-colored eggs. Then our salmon came back again, and, softly covering the eggs, the work of their lives was done, and, in the old salmon-fashion, they drifted, tail foremost, down the stream.

Next morning, a settler in the Bitter-Root region, passing by the brook near his house, noticed that a "dog-salmon" had run in there and seemed "mighty nigh tuckered out." So he took a hoe, and, wading into the brook, rapped the fish on the head with it, and carrying it ashore threw it to the hogs. But the hogs had a surfeit of salmon-meat, and they ate only the soft parts, leaving the head untouched. And a wandering naturalist found it there, and sent it to the United States Fish Commission to be identified, and thus it came to me.

QUESTIONS AND EXERCISES

It might seem at first thought that this passage is narrative, but the writer's ultimate purpose is not to tell a story about a salmon; rather it is to elucidate the habits of the salmon, and for this elucidation he chooses the narrative form because of its greater interest.

1. Divide the account into its stages. Determine whether these are in the time-order or some other.

2. Are the events those that happened in the case of a particular salmon, or are they what might have happened to any fish of that kind? Is the writer concerned really with an individual salmon or with the whole class of salmon?

3. Note the abundance of definite detail in this account. Point out places where vividness is secured through specific, concrete words, or through apt figures.

4. In general, how far is this like a narrative? What is gained by the narrative method? State the material without the narrative treatment, and compare effectiveness.

Exercise 1. Write a 600-word composition on one of the following subjects. In your explanation use the narrative method. Have abundance of detail. Use concrete words freely.

The story of an oak tree.
History of a frog.
The story of wheat.
The story of the blue-jay (or other species of bird).

Exercise 2.—Write a composition on The Making of an Engineer (or any other professional man). Select a single concrete case, and tell the story with as much interest as possible.

REFINING CRUDE PETROLEUM[1]

WALTER SHELDON TOWER

The enormous supplies of petroleum in this country never had any great industrial value until some method of purification or refining was invented. The early attempts to use

[1] Reprinted by permission of D. Appleton & Co., from *The Story of Oil*. Acknowledgment for the suggestion of this selection is made to Grose's *Specimens of English Composition* (Scott, Foresman & Co.).

the crude oil for domestic lighting purposes in various places were invariably unsuccessful, on account of the sooty, smoking flame, and the extremely disagreeable, nauseous odor. Use as an illuminant was the only avenue of development which seemed to offer any real possibilities, but it was absolutely necessary that the quality of the oil should be improved by the removal of these objectionable features, if its use were to become general.

Purification of petroleum was done in a rough way many years before the modern process was perfected, but never on a very important scale. The medicinal oils used in European countries two centuries ago were generally subjected to some process of distillation or filtration. Refined illuminating oil from the Galician districts was introduced in the early part of the last century, and soon after that time filtering through charcoal was tried in this country to remove the odor and improve the general appearance of the crude oil. The first important refining plant in the world, however, was probably erected in the Baku district about 1823. It consisted of an iron still having a capacity of forty buckets, and said to give about sixteen buckets of so-called "white naphtha" from each charge. This refined oil found a ready sale at the great Russian fair at Nishni Novgorod, presumably to be used in lamps.

Petroleum refining in this country began in a small way about 1855, with Kier's experiments to turn his medicinal oil to some more valuable use. The manufacture of so-called "paraffin oils" from coal and shale had increased so rapidly in the decade following 1850 that there were some fifty or sixty establishments in the eastern part of the United States when Drake's well was opened. Kier's results had already shown clearly enough that paraffin oils could be secured more easily from petroleum than from coal or shale, and more cheaply also if the supply of petroleum were large enough. The prospect of securing petroleum in large quantities by following Drake's example made the entire shale oil industry totter. The owners of the refineries, many of which were then only fairly started, saw themselves facing ruin, until a simple and easy salvation

appeared in converting their plants into petroleum refineries. Thus, the latter industry was able to profit immediately from the existence of this large number of ready-made establishments.

Kier's first attempts at refining petroleum had given him a "carbon oil" distillate, distinctly superior to the crude oil, but far from being perfect. The strong odor still persisted and brought a storm of complaints from the consumers. General dissatisfaction was expressed also on account of the rapidity with which the oil turned black, and on account of the formation of a hard crust on the wick which interfered with the free burning of the flame. As a result the "carbon oil" gained favor slowly, despite the fact that an army of canvassers and selling agents spread over the country to boom its use. Something had to be done to place petroleum oil on as satisfactory a basis as were the shale and coal oils. Distillation alone would evidently never suffice. Chemical treatment to purify the products after distillation was tried and soon demonstrated that successive manipulations with solutions of alkali and acid would remove the chief objectionable features. These improvements, already familiar abroad, had been introduced here about the time Drake went to the oil regions. Therefore, as soon as his well was struck, the refining of petroleum was in a condition to expand and drive the shale oil industry out of existence in short order.

The most important process in the refining of petroleum, as it is carried on to-day, consists essentially of two parts: first, heating the oil in a still until it vaporizes in the same way as boiling water passes into steam; and second, condensing these vapors just as steam condenses on cold objects. The successful separation of the different products depends on the fact that each of the many compounds composing crude oil has its own particular boiling point, and thus allows gradual heating to carry on the process of division, or fractional distillation, as it is called. The stills where the crude oil is heated, the condensers where the vapors of successive divisions are returned to the liquid form, and the tanks for storing the refined products,

therefore, represent the important parts of the skeleton of every refinery.

The early refineries were mainly small plants with a few vertical iron stills resembling giant cheese boxes, and having a capacity of twenty-five to seventy-five barrels each. As the industry expanded, however, and made constantly increasing demands on the capacity of the refineries, larger and larger stills were introduced. A horizontal cylinder still was found to offer various advantages over the old cheese box style, and the cylinder form, with a capacity of about 600 barrels, is the type now generally used in this country.

Each still may have its own condenser, or several stills may be connected with a common condenser, although the former arrangement is preferable. In either case the condenser is the same, consisting of coils of three or four inch pipe several hundred feet long, and ordinarily kept cool by thousands of gallons of water pumped over them daily. The hot vapors entering the condenser from the still come in contact with the cold pipe and return to liquid form, in the same way as steam on a winter day will collect on the cold glass of a window and trickle down the pane in tiny streams of water. The refined product of a dozen condensers may be turned into a single receiving tank until the limit of its capacity is reached, and then other similar tanks are pressed into service.

Between the condenser and the receiving tanks, the distilled oil has to pass through the stillhouse and undergo the keen scrutiny of the stillman, on whose skill the success of the entire process depends. The condensed distillates make their entrance to the stillhouse through a V-shaped tube, such as are commonly inserted in drain pipes to prevent the passage of sewer gas, and which serves much the same purpose here. A vertical pipe on the condenser side of the V allows the uncondensable gases from the still, that is, those vapors which will condense only at very low temperature, either to escape into the air or to be led away to be burned under the still from which they came. The condensed distillate, now in the liquid form again, passes through the V tube and enters the stillhouse in what is called

the separating box, a triangular, cast-iron affair. A glass door on one side of the box enables the stillman to watch both the color of the oil and the size of the stream as it enters the box. In this way, from the knowledge of long experience, he knows how to regulate his fires under the stills, and from occasional samples of the distillate he can determine when a different grade of oil has begun to vaporize in the still and is coming through the condenser. Shutting one valve and opening another close at hand turns the stream into a different receiving tank. So the process goes as long as separation is possible, or until some special requirements make it desirable to stop the distillation at a certain point.

The actual process of distillation consists in carefully separating the different hydrocarbon compounds which make up the crude petroleum. These "fractions," as the different compounds are called, are determined more or less arbitrarily by their weight as compared with an equal bulk of water, and by the ease with which they give off inflammable vapors.

Distillation may be done by what is known as the *intermittent process*, in which the major part of the operation is carried on in one still heated to successively higher temperatures by gradually increasing the fires beneath it. This method is most commonly used in the United States. Distillation may also be done by the *continuous process*, in which the crude oil is pumped through a series of stills, each succeeding one being heated to a constant temperature higher than that of the one preceding.

In the intermittent process, the crude oil in the still is subjected to a gradually increasing temperature, so that the different fractions pass off to the condenser in the order of their volatility. The lighter and more volatile compounds, that is, those boiling at low temperatures, are vaporized first, the heavy, less volatile compounds not appearing until the highest temperatures are reached. Different petroleums vary so widely in character, and the number of possible products is so large that each kind requires special treatment to secure the particular products for which it is best adapted. The distilling business, therefore,

becomes decidedly intricate when examined in detail, and a high degree of skill must be exercised in manipulating the process so that it will yield the largest quantity and best quality of the valuable oils.

The general character of the treatment can be shown by comparing the two common processes known as "running to tar" and "running to cylinder stock." The main difference between these two processes is that the former gives the largest possible yield of illuminating oils and a small yield of heavier products for lubricating. The second process is intended to yield a maximum amount of the lubricating oils, with the illuminating oils of secondary consideration. In general, therefore, one process is the direct reverse of the other in so far as its chief object in view is concerned.

Both processes start with crude oil heated in the still, and the vapors passing off into the condenser. The most volatile of these vapors begin to appear before much of any heat is applied to the still. They can be condensed only by special processes at temperatures near the freezing point, consequently in the ordinary course of distillation they pass off into the air through the escape pipe from the condenser or are led under the still to serve as fuel. The first distillate which condenses and passes through the V tube to the stillhouse is a clear, colorless light oil, but, as the process goes on, the stream of oil entering the separating box becomes heavier, and the color gradually changes through yellow to darker shades. The stillman tests the density of the oil from time to time, and on the basis of these tests and the color, he turns the stream into different tanks, by simply closing and opening convenient valves.

The stream passing through the separating box is continuous as long as the still contains any oil which can be vaporized, hence the stillman's divisions of the stream of distillates, or his "cuts," as they are called, are an exceedingly important part of the process. The first cut is usually made when oils of the naphtha class cease to appear. The second cut is the illuminating oil. In the "running to tar" process, the method known as "cracking" is employed after about two-thirds of

the cut of illuminating oil has passed over, its object being to increase the proportion of illuminating oils obtained.

The exact changes which take place in the still during this "cracking" process are only partly understood. The process was discovered accidentally in 1861 by a stillman at Newark, N. J., who left his post one day after about half the contents had passed off, building a strong fire under the still to last until he returned, as he expected, a half hour later. Several hours elapsed, however, before he did return, and then, to his amazement, he found issuing from the condenser a lighter distillate than was being obtained when he left, whereas it should normally have been much heavier. Such an entirely unheard of thing led immediately to experiments, in which it was found that a portion of the heavy distillate, normally coming through the condenser last, had condensed on the cooler upper portion of the still, and dropping back on the highly heated liquid had encountered a temperature hot enough to cause decomposition of some sort, so that a lighter oil was the final result. Many different devices have been invented to aid in this cracking process, and, though some refineries use it but little, cracking has been of enormous benefit in the case of certain petroleums, naturally yielding only a small percentage of kerosene, yet rich in the grades heavier than kerosene, and not heavy enough to be high quality lubricating oils. By cracking, many of these intermediate grades are broken up, and become valuable illuminating oil.

After cracking has given as much kerosene as can be secured the fires are checked, and the tar process stops so far as the first still is concerned. A certain amount of thick residue, or "tar," always remains in the still and must be removed before the still can receive another charge of crude oil. This tar usually goes to a second still, where further distillation gives lubricating oils, paraffin wax, and coke. The cuts of naphtha and illuminating oils are also either redistilled or subjected to further treatment to purify them and separate them into different commercial grades.

The process known as "running to cylinder stock" is essen-

tially the same as the other up to the point where cracking would begin, except that it is usually applied to crude oils naturally adapted to the manufacture of lubricants. The important difference consists in heating the still by free superheated steam within, as well as by the usual fire underneath the still. The presence of the steam causes a more even distribution of the heat, and more completely vaporizes the volatile lighter oils from the whole charge without having to subject it to such a high temperature. When the distillate in this process appears too heavy for kerosene, instead of the cracking treatment, a third cut, known as the "wax slop," is often made. Different methods of handling this cut yield special brands of oil for a great variety of purposes, from the headlight oil of locomotives to the thin "spindle oils" used to lubricate light machinery. The entire elimination of the cracking process leaves a greater residue in the still after the "wax slop" cut is made and this residue, known as "cylinder stock," forms the basis for the manufacture of a host of lubricating oils.

The Russian process of continuous distillation differs from the American method only in using a series of a dozen or more stills, each of which is heated to a definite steady temperature. The crude oil passing from one still to another encounters these successively higher temperatures, which correspond to the boiling points of the different petroleum products. Each still constantly gives off a distillate of uniform character, while the series of stills gives the same range of distillates as are obtained by the gradual application of increased heat in the intermittent system. The possibility of supplying the crude oil to the stills as fast as the distillates pass off results in important economies of time, less waste of fuel, and a minimum of injury to the plant by avoiding the cooling and reheating of the still. This process, however, is not well adapted to American conditions because of differences in the nature of the crude oils, and in the products most desired. The American refiner, in general, aims to produce as much kerosene or lubricating oils as possible, whereas in Russia the enormous demand for the residuum, or *astatki* for fuel, makes it nearly as valuable as any other product. There

is, therefore, little inducement to increase the yield of kerosene and reduce the quantity of residuum by employing the cracking process, which can be done only in intermittent distillation.

The first distillates obtained from the crude oil by either process usually have to be redistilled or purified before they can be used. Any sulphur which is present must be removed either in the first process or subsequently. One method makes use of copper oxide in the first condenser, or in a specially constructed still, the sulphur by chemical union being removed in the form of a copper sulphide, from which the copper can be reclaimed and used over and over. Another method makes the separation by treating the distillates successively with sulphuric acid, caustic soda and litharge in agitator tanks built for the purpose, the removal in this case being in the form of a sulphide of lead. This treatment for sulphur is one of the most important and yet most troublesome processes of all, since the presence of a very small percentage of sulphur imparts a highly disagreeable odor to any distillate. No product can be sold until the last trace of sulphur has been removed.

The naphtha distillate, where obtained in important quantities, may be roughly separated into different grades, or cuts, known as gasoline, commercial naphtha, and benzine. When the division is made by the stillman, as they come from the condenser, washing with acid, water, caustic soda, and water again, in the metal agitators, to purify and deodorize is the only further treatment necessary before they are ready for shipment. More often, however, all the naphtha distillate goes into a single cut as it comes from the condenser, is subjected as a whole to the deodorizing and purifying treatment and is then redistilled and divided into the three fractions mentioned above. This redistillation of the naphtha is done in a special still heated by steam, and with the outlet, through which the vapors reach the condenser, rising for some distance before it actually enters the condenser coil. This arrangement is introduced to prevent any liquid from being carried over into the condenser with the gas. The condenser for the naphtha still also differs from the others in having two coils of pipe, the first of which has a "back trap,"

or pipe leading back to the still, so that any heavier oils present, condensing quickly, will be returned to the still. The main body of the naphtha distillate is condensed in the second coil of pipe, and is cut into standard grades by the usual separating-box method, but, in order to secure the very lightest of the products, it is necessary to use a third coil surrounded by a freezing mixture of salt and ice. The different cuts obtained from this distillation are immediately ready for use as soon as tested to prove their quality

The distillate of illuminating oil, or kerosene, as we know it, if used just as it comes from the original still, has all the disadvantages which Kier's "carbon oil" presented, charring the wicks, giving off an unpleasant odor, and rapidly turning to a dark color after standing, all owing to the presence of various impurities. The illuminating "cut," therefore, is given the same sort of purification treatment as is applied to the naphtha. Testing and grading for sale then complete the last stages in the production of kerosene.

The manufacture of lubricating oils, and paraffin or wax complete the principal processes of refining. Some lubricating oils are produced by the processes known as sunning or reducing, depending on the evaporation of the lighter products either by exposing the crude in open tanks or by gently heating it with steam. This method of treatment is said to have originated from the observation that certain oils spilled on the streams of the oil regions were thickened by evaporation, and became fit for lubricating purposes without further treatment. Experiments with different oils showed the possibility of making natural lubricators in this way from special grades of crude petroleum. So-called "sunned oils" and "reduced oils" are still to be found on the market, but by far the greater proportion of machine oils are products of distillation.

These refined lubricating oils come either from the process of "running to cylinder stock," or from the redistillation of the "wax slop" and of the tar left in the still after cracking for kerosene is completed. These oils, in one way or another, form the basis of all grades of machine oil from the very lightest

"spindle oil" to the heaviest grease. The processes of treatment differ only in minor details from those used for the lighter oils. Different cuts are made, and these cuts, together with varying methods of purification, bleaching and filtering, determine the particular grade produced. In general, however, the redistillation of the "wax slop" cut yields the major portion of the light and especially high-grade lubricating oils, while the heavier grades come from the cylinder stock.

Paraffin was once regarded merely as a by-product of distillation, but it is now so widely used in industrial processes that in some refineries it is fully as valuable as any of the other products. Paraffin is obtained from the redistillation of either the residuum left in the tar process after cracking is completed, or from the "wax slop" cut in the cylinder-stock process. In either case the paraffin distillation is carried on in heavy steel stills at very high temperatures. The paraffin passes off in one long stream of distillate, the latter end of which may be almost pure wax. It then undergoes the same chemical purification as the other products, the only difference being that the agitator must be heated to prevent cooling and solidification of the wax. The subsequent treatment, however, is much more complicated, consisting of a variety of steps as follows: to a settling tank where the water is removed; to a chilling tank where ammonia machines cause it to congeal and crystallize; to a filter press which forces out any oil remaining, and leaves only solid paraffin; to the melting tank to be converted into liquid paraffin again; to the bone-black filter where all color impurities are removed; and, finally, to the second chilling tank, where it is returned to the crystallized form ready for the hydraulic presses, which convert it into cakes for shipment.

From this description it appears that only two of the important products of petroleum are regularly obtained directly from the first distillation; these are the illuminating oils and the cylinder stock, and both of these have to receive additional treatment subsequently. All other products are the result of a second distillation and of chemical manipulations. The percentage of the different products obtained by refining varies

immensely, depending both on the original character of the crude oil and on the special aims of the individual refiner. Illuminating oils run as high as seventy-five per cent. or eighty per cent., and as low as twenty per cent. to twenty-five per cent. Lubricating oils vary from nothing up to twenty per cent., or thirty per cent., and the residuum and waste may be as high as thirty per cent. of the whole volume of crude oil. The residuum, representing the compounds which cannot be vaporized by ordinary means, is not, however, all loss, because, whether pitch, coke, or asphalt, according to the character of the crude oil, various methods of treatment and utilization are devised. Practically nothing is lost except moisture, solid impurities, and the varying amounts of uncondensed gases. Even the water used in washing the distillates is sent to huge settling tanks to recover any oil which may have been included in it.

The most volatile of these distilled oils, the naphthas, are extremely inflammable liquids, the gases from which make violently explosive combinations when mixed with air. The presence of a very small percentage of the lighter naphtha oils in illuminating or lubricating oils is, therefore, a constant source of danger. If such oils are used explosions and fires are sure to occur. The danger is especially great in the case of naphthas present in kerosene, the most prolific cause of lamp accidents and fires in the early days of the industry. Continued complaints about the "deadly kerosene," as it was frequently called, led to the establishment of certain legal standards which all illuminating oils must meet. It has consequently become customary to subject all the distilled oils to standard tests in order to insure a uniform quality of the product. Testing is now fully as important a part of the refining process as is distillation itself, since it is the only safeguard for the interests of both producer and consumer.

The lighter oils of the naphtha group are usually tested for gravity, odor, and acid impurity. The gravity test is made with the usual Baumé hydrometer, and on the basis of this test the oils are graded for commercial purposes, as gasoline, naphtha,

and benzine. The test for odors is made by simply saturating a cloth with the oil, as the oil evaporates from the cloth any foreign odors are readily detected. The presence of acid is revealed by testing with litmus paper, which immediately turns red if the acid has not been entirely removed. Benzines for special purposes, as in the manufacture of paints and varnishes, also have to be free from any of the heavier oils. The test in this case is made by soaking part of a sheet of paper in the benzine, if heavier oil, like kerosene, is present, a grease spot shows as the volatile benzine rapidly evaporates; otherwise the whole sheet of paper presents the same appearance.

The testing of kerosene oils is by far the most important of all, because the conditions under which it is used in ordinary lamps are especially favorable for the occurrence of explosions. Kerosene is tested for acid, sulphur, gravity, color, and what is known as the "fire test." Acid and gravity tests are the same as for naphthas. Color is, of course, determined by inspection, and furnishes the basis for division of the kerosene into the three grades common in this country: *water white*, which is colorless, and is the standard of American kerosene; *prime white*, of a faint yellow color; and *standard* or *standard white*, a pronounced yellow. In European countries other grades are recognized, as many as seven being commonly sold in Germany.

The fire tests, however, are the most significant since they determine the safe or unsafe character of the kerosene and the legality of its sale. Two fire tests may be used, one of them called the "flash test," determining the temperature at which the oil will give off an inflammable vapor when heated artificially, or when exposed naturally to the air. The other, known as the "burning test," determines the temperature at which the oil will take fire and burn on the surface. The latter temperature is usually from ten to forty degrees higher than the "flashing point," and, since the gravest dangers are from the generation of explosive vapors, the flash test means most.

A great number of devices have been invented for making the flash test, the essential principle of each being a closed or open cup in which the oil is heated. A common form of tester

consists of a cup holding about the same amount of oil as a medium-sized lamp, the cup being immersed in water and heated carefully by heating the water, on the same principle as cooking in a double boiler. The glass cover of the cup has a hole for a thermometer and another for inserting a match to ignite the vapor. Kerosene, to be safe for lighting purposes, should have a flashing point higher than any temperature which it is likely to reach under ordinary conditions. In most places a flashing point of 110° or higher is required by law. Testing, however, usually begins as soon as the thermometer shows the oil to have a temperature of about 85° or 90°, and continues at intervals of every degree or two until the insertion of the match causes the appearance of a bluish flame in the cup. As soon as this "flash" flame appears the reading of the thermometer indicates whether the oil is up to the required standard. Illuminating oils for special purposes such as headlight oil for locomotives, signal lamps, miners' lamps, and so on, frequently have to meet much higher requirements than for ordinary domestic use, but the testing process is the same.

Lubricating oils are subjected to three important tests, viscosity, fire test, and cold test, each, in a way, being of vital significance in determining the value of the oil. The first, if any, is perhaps the most important since viscosity is the most necessary quality of any lubricating fluid. The test may be made in innumerable ways, but all depend on the principle of determining the length of time required for a given quantity of the oil to flow through a small opening. The temperature at which the test is made depends on the special use for which the individual oil is intended, ranging up as high as 212° in the case of cylinder oils for steam engines.

The fire test is necessary in the case of most machine and engine oils because the heat from friction might generate inflammable vapors if very volatile products were present. The cold test is also required to determine the temperature at which the oil would become thick and cloudy. This test is made by freezing the oil in a tube, and then as it melts, noting the temperature at which it begins to run. High-grade lubricating oils

have to withstand a very wide range of temperatures; first quality cylinder oil, for example, must have a cold test as low as 55°, and it must not flash below 550° Fahrenheit.

All these tests must be made at the refinery, for each lot of distillates before they can be approved, graded, and loaded for shipment to the consumer. If any distillate does not "prove up," it has to go back for further manipulation to remedy the defects, the success or failure of the tests depending largely on the skill of the stillman in making his cuts as the distillate passes through his separating box.

In spite of its many steps and intricate processes there is nothing picturesque or spectacular in petroleum refining unless it is in the magnitude of the plant and the very obscurity of the many transformations going on everywhere yet entirely unseen. One refinery is essentially the same as every other save in size, and perhaps in a few minor details. At a hundred refineries from the Atlantic to the Pacific, and from the Lakes to the Gulf, the same story is repeated day after day and year after year, as the invisible stream of oil makes its journey step by step through the maze of pipes, stills, condensers, and agitators, leaving at every turn a part of its precious burden. On the one hand, the vast network of pipe lines binds the refinery to thousands of wells, scattered halfway across the continent. On the other hand, the world-distributing system carries the multitude of refined products into the daily life of every class of humanity.

QUESTIONS AND EXERCISES

This simple and clear explanation of a long and complex process further illustrates narrative methods in exposition.

1. In what way do the opening paragraphs arouse the reader's interest?

2. What are the several steps in the process of refining petroleum? Has the writer explained a single instance of refining; or, has he made his explanation by gathering up certain common features of the process under all circumstances?

3. Does the piece as a whole give the impression of an attempt to explain some one thing—to bring out a central idea—or does it seem

to be rather a mere succession of ideas? Does the selection finally produce on the mind of the reader a single clear idea?

4. Are the proportions of the piece good? Is the largest part of the explanation given to the most important stage of the refining process? In the case of small topics is the explanation clear and full enough?

5. How far is description employed? Would pictures or diagrams help to make explanation clearer?

Exercise 1. In writing upon one of the subjects given below, first consider carefully the main things that are to be explained. Reduce the process to three or four principal stages or parts, if this is possible. Then group all minor points under these heads. Use a diagram if you find it necessary.

How paper is made.
The printing of a newspaper.
How hay is cured.
Raising tobacco.
Driving a well.
How to resuscitate a drowning man.
Making a screw-driver blade.
How to build a temporary shelter for camping in the woods.
How a cement sidewalk is laid.
How electroplating is done.
The manufacture of ice.
The making of lead pencils.
The daily routine of a bank.
How to make blue-prints.

HOW MAPS ARE MADE.[1]

W. B. Blakie

The subject on which I am deputed to address you to-night is what, in the slang of the day, may be described as "a very large order." Though the title seems simple enough, the subject itself is so large and it spreads and ramifies itself through

[1] Read at a meeting of the Royal Scottish Geographical Society in Edinburgh and Glasgow, April, 1891. Reprinted from *Scottish Geographical Magazine*, Vol. VII, p. 419.

so many arts and sciences, that the temptation to go off from the distinct line of my subject into the different branches that introduce themselves is great, and all these branches are to me so interesting, that I have found great difficulty in confining myself strictly to the story of how a map is made. I have forced myself, however, to stay on the center line of map-making, and I hope, before the evening is over, to give you a clear and distinct idea of the principles on which a map is made, for the subject of my paper is not "How maps are drawn," but "How maps are made;" and I will attempt to show you the naked machinery of the process.

I have often been amazed at the popular ignorance of what would seem to be the very first principles of geography and of map-making, and this has induced me to begin at the very A B C of the subject. I intend throughout this paper to avoid technical phrases and mathematical terms. I have nothing new to tell you; much that I am about to say is known to every person here present, and I ask you to bear with me if occasionally I seem childish in my descriptions.

One thing more I should like to premise, and that is, that in this paper I do not propose to go into any great detail, or to confuse anyone here with the numberless scientific corrections and modifications that have to be made in all scientific calculations. I will speak only on general principles; those who know the science thoroughly will understand the modifications necessary, while those who have not the same advantage will, I trust, be able to grasp the principles of what is shown.

My intention to-night is to show (1) how a spectator finds his position on the earth's surface; (2) how he defines and records that position; (3) how he makes a map from the information he has found; (4) how he fills up the details of that map; and (5) briefly to describe how the map so made is drawn and printed, and incidentally to show the use of the various tools and instruments employed in these operations.

I assume that we all know that the earth is (roughly speaking) a sphere, spinning round on its axis once in twenty-four hours. Now, if we take up a sphere, like this ball, and mark a spot on

it, there is nothing whatever to define its position; no north, no south; nothing to guide us. One point on this sphere is the same as any other point, until we find some reference spot to measure from; but we have assumed that we know that the earth spins round on its axis, and here we at once discover something we can measure from. The ends of the axis of the ball, which we call the poles, are, we see, at rest compared with the rest of the surface of the spinning ball.

Now, this so-called polarity gives us at once two points of reference. Although no one has ever been at either of the poles, the study of the subject for hundreds of years has proved their existence as surely as if the poles had been visited and been discovered marked with upstanding posts. Between these two points, which we call the poles, I can mark a point half-way, which, by spinning the ball in contact with the pencil, I convert into a line called the equator, the equal divider, popularly *the* line. You will observe that this middle line, this equator, is also the largest possible circle on this sphere, and it is from this circle that all measurements and references north and south are made. We see on the globe and on maps a number of other circles parallel to the equator to the north and south of it, and drawn at equal distances. These are called the *parallels of latitude* (or wideness), and they mark certain degrees of *angular divergence* from the equator.

Consider for a moment what this means. In the first conception of them these lines have no specific distance apart, because they really are angular measurements, and it is this conception of them I wish to get hold of. A degree of latitude is not necessarily a number of miles, and until we know the actual diameter of the earth we can not tell what the length of a degree is. It is a proportion of the circumference of a circle, a fractional measurement of it. We may speak of a half, a quarter, of anything, but, until we say what it is a half or a quarter of, the phrase conveys no idea of magnitude. It might be half a mile, or half a kingdom, or half an inch, or half a crown. Similarly, a degree of a circle means nothing so far as length is concerned, until you know the size of the circle, when you can

at once calculate, with the proper mathematical knowledge, the numerical value of a degree at the earth's circumference.

Now, having marked these lines on the surface of the earth, we have certain marks on our globe to which we can refer any and every point. It may be said, "Why mark these lines on the map? They do not exist; they are only imaginary." Quite true! But then the first principle of all map-making is to begin with imaginary lines, from which to measure the position of every place on that map; and all such imaginary lines are carefully recorded, as we shall see later on, so that they can be accurately laid down at any moment by those who know how to find them. We find them a great convenience, an absolute necessity, indeed, so we leave them drawn on the globe. Imagine a street—any street will do, but for a good analogy imagine a street built, like Moray Place, in a circle. We can say, speaking of, say, a water plug, or any point in that street, that it is on the center line of the street, or the line of the lamp-posts, or so many feet to one side or the other of either of these lines. There is no visibly marked center line or line of lamp-posts, but it can be filled up in a moment by human intelligence, and if there were to be frequent references to them these lines would be marked on a plan for constant use. The parallels of latitude are similar lines drawn for convenience or reference.

The circumference of the earth, like any other circle, is divisible into 360 degrees, and we number the parallels by the number of degrees of angular divergence; only, instead of beginning at a pole and going right round, we, for convenience sake, begin at the equator and then number 90 degrees towards the North Pole and 90 degrees towards the South Pole.

But one set of reference lines is not enough; we must have another set, and we get them in the *meridians of longitude*. We draw these through the poles at right angles to the equator. They are all "great circles;" that is, each circle is concentric with the globe. The equator being a circle, we divide it as before into 360 degrees, and the meridians through the points of section from a second system of lines of reference. But, unlike the parallels of latitude, they are all the same size. One is

the same as another. How are they to be numbered? Go back for a moment to Moray Place, and remember the lines we drew—the center of the street, and the line of the lamp-posts. How are we to define a spot on one of these lines? They are circular, and consequently have no beginning and no end. What we should do would be to mark a convenient spot with a flag, or a peg, or a stone, and say, "That is the beginning; measure from that."

This is exactly what we must do in longitude. We must mark a starting line on the earth, and call it zero; and as all nations have a free choice they have not chosen the same. We have chosen the meridian of Greenwich, the French that of Paris, the Americans Washington, and the Russians Pulkova and the Germans used to use Ferro; but for all English maps, and now for most foreign ones, the meridian of Greenwich is the starting line, the zero of longitude.

The custom here again is not to reckon 360 degrees round the circle, but to reckon 180 degrees east and 180 degrees west. We saw that latitude was angular divergence from the equator; but what are these degrees of longitude? Look at a ball spinning round opposite a candle. We assumed a knowledge that the earth spun round its axis in twenty-four hours. Every part of it comes in turn opposite a heavenly body (say the sun) once in twenty-four hours, just as every part of this ball comes opposite the candle once in each revolution. Longitude is, then, angular divergence measured by the *difference of time* in coming opposite a heavenly body. As the circle is divisible into 360 degrees, so the day, *i. e.*, the revolution of the earth, is divisible into twenty-four hours, and one hour of longitude is consequently equal to 15 degrees. In maps longitude is marked in degrees, while in almanacs the elements given to reckon it are always written in hours, minutes, and seconds.

Remember once more, that these degrees are not lengths measured on the surface, but are the record of angular divergence from the initial meridian. It is all the more necessary to bear this in mind, because the length on the surface of the earth of a degree of longitude varies enormously, being greatest at

the equator and nothing at all at the pole, differing thus from degrees of latitude, which, roughly speaking and for the purposes of this paper, may be considered equal.

The idea that latitude and longitude are the measures of angular divergence and not absolute distance in miles or yards may be easily grasped by familiar illustration. If you can imagine two travellers leaving Italy by road, the one over the St. Gothard pass and the other over Mount Cenis, and two other travellers following them by rail at such an interval of time that they are in the railway tunnels at exactly the same moment that the pedestrians attain the summits of the passes; the pedestrians on the mountain and the railway traveller in the tunnel of the St. Gothard pass will be in exactly the same latitude and longitude, and so will the travellers by the Mount Cenis routes. The pedestrians however will be about 60 yards farther apart from each other than the railway travellers. The reason of this of course is that the pedestrians are farther away from the earth's center, but their angular divergence from the equator and the earth's axis are precisely the same, whether they are on the mountain or in the tunnel 5,000 feet below.

Now, having defined latitude and longitude and shown how the lines representing them are drawn, we must see how in practice the surveyor finds the latitude and longitude of a place, and thereby begins his map. The poles, as we saw, are first points to measure from, and the equator the half-way line. It is evident he can not measure directly a line from pole to pole, find out the half and call it the equator, and leave pegs at each parallel in passing. He must look to things outside the earth itself from which to reckon, and he gets such reference points in the heavenly bodies. To his eye these are situated in the great vault of the heavens. He sees them as if on the surface of a hollow globe continually revolving around him, rising in the east till they reach their highest point above him, called the culminating point, then setting in the west. For thousands of years astronomers have studied these bodies, and fixed their apparent positions in the celestial vault; and these positions are recorded with the utmost possible accuracy in a book, com-

piled by Government, called the *Nautical Almanac*, and, from the practical information given there, the surveyor finds his position. He may take the sun or he may take the stars, but the positions of the sun being affected by the motion of the earth round it, I propose to take a star to illustrate my next remarks, as its movements are simpler.

The pole of the heavens is the end of the axis of the earth infinitely prolonged. The intersection of the plane of the equator with the celestial vault is called the *equinoctial*, and as the angular divergence on the surface of the earth is measured in degrees from the equator and called latitude, so the angular divergence of a heavenly body from the equinoctial is called its *declination*. As the angular divergence from the meridian of Greenwich was called longitude, so the divergence in time from a starting point in the heavens is called *right ascension*. We had to fix arbitrarily the meridian of Greenwich as a starting line on the earth. We have also to fix equally arbitrarily a starting point in the heavens, and that point may be most simply described as the point in the heavens in which the sun is in spring, when the day and night are equal.

The latitude of any place on the earth's crust is equal to the altitude of the celestial pole. You can see this in a moment if you imagine yourself on the equator and look to the pole, marked, say, by the Pole Star. You will see it on the horizon and of no altitude at all; and at the equator you have no latitude, or it is called zero; but, as you approach the pole, the Pole Star will gradually appear to rise higher and higher until when you reach the North Pole it will be directly over your head, and consequently at right angles to, or 90 degrees from the horizon, and your latitude is then also 90 degrees. But though the Pole Star is very near the North Pole, it does not actually coincide with it, and we must find some other way of finding our latitude accurately. We get this by taking the altitude of any known star in various ways. I will explain the simplest method, of which all others are only slight modifications:

(1) Measure the *meridian altitude* of the star—that is, its highest altitude above the horizon.

(2) Deduct that altitude from 90 degrees, which gives its *zenith distance*, or the angular distance from a point exactly over your head.

(3) Add (or subtract) the *declination* of the star (found in the *Nautical Almanac*) to the *zenith distance*, and the result is your latitude.

I have here a diagram showing how the latitude of Edinburgh would be found from the bright star Arcturus, which "culminates," or reaches its highest altitude, on our meridian a few minutes before 12 to-night.

I measure first its *altitude*, which I find is 54 degrees. Deducting that from 90 degrees gives its *zenith distance* = 36 degrees; to that I add its *declination*, which I find from the almanac is 20 degrees, and the result is 56 degrees = the latitude of Edinburgh.

Longitude is a more difficult matter, and I have no time to go into it anything like fully. You will find a beautiful description of it in *Herschel's Astronomy*, the best by far of all popular books on the subject. While latitude is absolute, longitude, being difference in time, is relative, for there is no such thing as absolute time; and noon at any place is merely the moment when the sun culminates on the meridian. If the observer has a clock whose going he can depend on, and he sets it to, and keeps it always at, Greenwich time, he knows from that clock or chronometer what time it is at Greenwich when any star comes to the meridian. If then he can observe any astronomical phenomenon, such as the meridian passage of a star, he has only to observe the difference of the times recorded on the clock set to Greenwich time and on his local clock, and the difference is the longitude in time. This is the principle on which longitudes are taken at sea, where chronometers can be kept undisturbed, but for explorers on land it is more difficult.

The moon, however, is a natural clock, very complicated, but still readable to the initiated. It is continually moving through the stars, and its angular distance from prominent stars is carefully computed for Greenwich, and recorded in the *Nautical Almanac* for every hour in the year. The observer then finding

the moon's position by observation, and recording its local time, can find in the *Nautical Almanac* when it had the same position at Greenwich, and the difference of the times is the measure of the longitude.

In old days, when ships met, the first question was, Who are you? the next, What's your longitude? The invention of the chronometer by Harrison one hundred and twenty years ago has however, for sailors at least, vastly simplified the finding of longitude at sea: and I find from inquiry among sailors, that "lunars" are practically a lost art. In illustration, I may state that I find from the *Nautical Almanac* that Arcturus comes to the meridian of Greenwich at 11:37 to-night. If I have a clock or chronometer marking true Greenwich time, I shall find that this star will come to our meridian at twelve minutes and forty seconds later; the difference of longitude in time is therefore twelve minutes and forty seconds, which, converted into angular measurement, is 3 degrees 10½ minutes, the longitude (west) of Edinburgh.

Note here that at stations differing only in latitude the same star comes to the meridian at the same *time*, but at different *altitudes*. At stations differing only in longitude it comes to the meridian at the same *altitude*, but at different *times*. The instrument generally used for taking altitudes is the sextant. At sea, where we have a visible horizon—the line where the sea meets the sky—we measure altitudes from this horizon; but on land we have no true horizon, and then we use, what is more accurate, an *artificial horizon*, which is a cup of mercury in which the heavenly body is reflected. Measure the angle between the real body in the sky and its reflection in the mercury, and half the angle is the true altitude.

Having discovered our position on the surface of the globe, we come to the representation of it on a flat sheet or map.

The Latin dictionary tells us that "mappa" is a sheet or napkin. Now, the surface of the globe is curved, and in a map we have only a flat surface to represent it on, and we shall for a short while study how this is done, as it is the basis of all map-drawing. The conventional representation on a flat

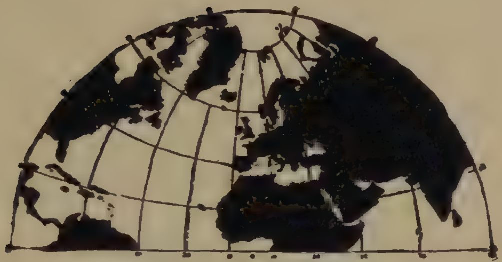
surface of the curved surface of the earth is called projection, because in its fundamental idea it is a picture of the globe projected or thrown forward from the eye on to a flat sheet; but this idea of it is so confusing to the mind unaccustomed to think out such things that, although it is the invariable way of describing it in all text books, I have preferred to show you three forms of projection without assuming any ideal throwing of the rays on to planes.

The first I show is the modified stereographic or equi-globular projection (Plate I), invented by Philip de la Hire about the end of the seventeenth century. A simple way of investigating this projection is to fit an iron ring over the center of the globe, and stretch tightly, from the North Pole to the South, india-rubber bands that coincide with the meridians of longitude on the globe, fastening them firmly to the ring at the poles. Similarly stretch india-rubber bands over the parallels of latitude, fastening them to the iron ring and to the meridians where they cross. While the ring is kept on the globe these india-rubber bands show the parallels and the meridians on the sphere. When the ring is lifted off the globe the india-rubber shrinks to a plane and shows exactly the lines of the stereographic projection. This is the projection used in all atlases for the world in hemispheres, for continents, and for large surfaces. It gives, indeed, a notion of rotundity and a general idea of projection, but the central portions are shrunk in, and the edges are distorted.

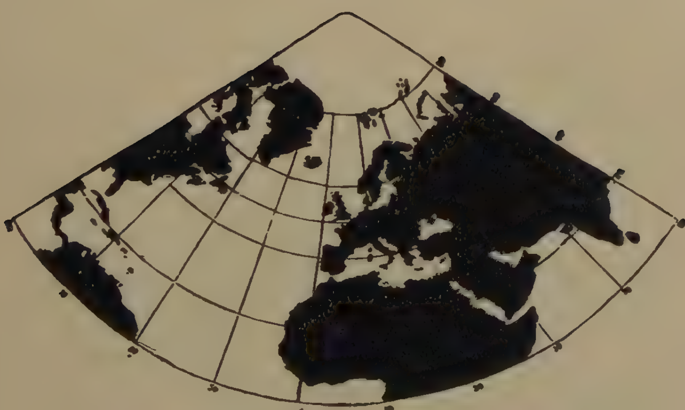
The next projection to be studied is Mercator's. Mercator was a Fleming who lived in the sixteenth century. He was almost an exact contemporary of John Knox. He was a writer on theology and geography. His real name was Gerard Kremer, which name, meaning merchant, he Latinized, in accordance with the custom of the day, into Mercator.

His invention is very clever. The construction of it is a little complicated, and is generally shirked in text books, but the actual idea is very simple, and I have here designed a piece of apparatus to illustrate exactly what I believe Mercator did when he evolved his system.

PLATE I

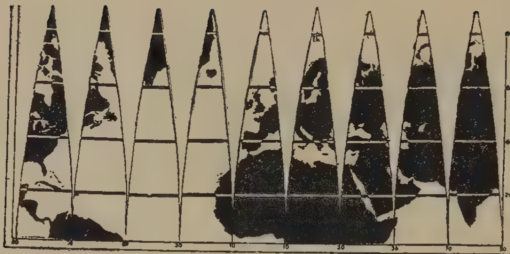


STEREOGRAPHIC PROJECTION



CONICAL PROJECTION

PLATE II



1. Gores from the globe.

1a

2. The gores stretched out horizontally to meet in straight vertical lines.

2a

3. The map distorted vertically in same proportion as horizontally

3a

MERCATOR'S PROJECTION

Though I have no direct evidence to show how Mercator argued out his system, I have not the least doubt that it was somewhat thus:

Mercator was a globe-maker, and no doubt worked from the globe. He stripped his gores off the globe, forming a map like this (Plate II, fig. 1), which was naturally very inconvenient, owing to the hiatuses between the meridians. He was obliged to join the gores along their meridians (Plate II, fig. 2). He then found that he had distorted everything, and the distortion increased in the higher latitudes, owing to the gores being further apart towards the top of the map. In order to restore a balance of orientation (or the relative position and direction of places), as he had distorted in longitude, so he had exactly in proportion to distort in latitude, as shown in Plate II, fig. 3, a complete Mercator's map of half the Northern Hemisphere, in which you will observe that the parallels are farther and farther apart as the latitude gets higher.

As these gores are not a familiar shape, I have a square here which will catch the eye at once (Plate II, fig. 1*a*). I distort it first by pulling it out horizontally as Mercator did in joining the meridians, and it ceases to be a square and the orientation is changed (Plate II, fig. 2*a*). I then distort it in height in the same proportion, and it becomes once more a square with the true orientation but larger than the original square (Plate II, fig. 3*a*). This is exactly what we did before with the gores of the globe.

Every parallel, in Mercator's projection, is a straight line, and every meridian is also a straight line. We have, then, an excellent sailing line from point to point. As Sir George Grove puts it very neatly (though he shirks the explanation of the projection), "The most ignorant sailor can lay down his course without calculation. In fact, the invention of this map has been justly called one of the most remarkable and useful events of the sixteenth century; because it enables common, unlearned people to do easily and correctly what only clever, learned people could have done without it."

Mercator's projection is that used in all nautical charts to

this day, because to the sailor it is far more important to know his direction or course than his distance, which with ordinary nautical knowledge, or from nautical tables made for him, he can easily calculate, but he needs to see his course.

In the conical projection (Plate I) we imagine a cone of paper to be rolled round the globe, touching it on the middle line of the map. Near their line of contact the map coincides very nearly with the globe surface, and is fairly accurate; but as it gets farther away from the touching point the distortion grows, the places being shown larger than in reality. For comparatively small areas, such as for maps of England and France, it is fairly accurate, and is the projection used in atlases.

In the illustrations (Plates II, I) we see the same globe projected on the same scale, but with very different proportions. These three projections are typical ones and the most commonly used, but there are many others. For those desirous of studying the subject the best work on it I know is the article by Mr. Taylor, in the June number of the *Scottish Geographical Magazine* of 1890, and to that article I refer them.

We have now seen how the traveller finds his place on the globe's surface, and how, when found, he can *project* or map that information on a flat sheet. We shall now see how a map will grow. Imagine a ship sailing into unexplored seas and coming to some land, say an island. The navigator at once fixes his position in the ship in latitude and longitude. The navigator's instruments are the sextant, the chronometer, and the mariner's compass. The general idea of the mariner's compass is that it always points to the north; but accurately this is not so. The general direction of the compass, or the magnetic pole, is not the true north, but a spot very considerably to the west of it, and, in fact, shifts continually; not only in different places, but even in the same place, the direction changes from time to time, as there are many local causes of disturbance. The navigator, then, to fix true north, must find his meridian—that is, he must observe the direction of a star or the sun when it culminates or comes to the meridian, and from this observation he computes the amount of local variation of the compass. In practice it is

not the moment of culmination he actually observes, but the statement is accurate enough for the purpose of this popular description. Knowing the variation of the compass, he can then take accurate bearings or directions to any feature he desires to record. Two or more such bearings to (say) a mountain, crossing each other from different known places, fix its position on the map.

We can now show how a country is mapped. Suppose a ship visits this island, and fixes, by the ways already indicated, a few latitudes and longitudes, and sails round it, fixing here and there points on the coast, and perhaps taking bearings of some mountain, then the island would be represented in an atlas with several points fixed and joined by dotted lines. Nautical surveying is always done with the sextant, which measures both vertical angles and horizontal.

Following in the wake of the sailor comes the explorer. I had intended, when I first sketched out this paper, to give an imaginary explorer's map of a journey across this island, but I have the privilege of showing you something so infinitely precious that I feel it would be a piece of bathos to concoct a sham map. Here I have two of Dr. Livingstone's own original manuscript maps, made on his last journey, kindly lent me for to-night by his daughter, Mrs. A. L. Bruce. Here we have no conjectures as to what the traveller might do; here are the real power, the actual materials of geography. Instead of imagining what an explorer should take with him, I may mention Livingstone's actual equipment: A 6-inch sextant, an artificial horizon, a pocket chronometer, a prismatic compass, and a pocket compass; two boiling-point thermometers and two common thermometers; aneroid barometer, a *Nautical Almanac*, and a book of mathematical tables.

The sextant, as we have seen, is for taking astronomical as well as terrestrial angles; the thermometer and barometer for taking heights. The principle on which the latter are calculated is the pressure of the atmosphere. The aneroid everybody knows; the boiling-point thermometer is considered better and more accurate, though I observe from Livingstone's notes,

who was the most painstaking and thorough observer, and who always observed with both, that there was little practical difference in the readings. Roughly speaking, water boils at sea-level at 212° F., and the barometer stands at 30 inches, while at 5,000 feet altitude water boils at 202.6°, and the barometer falls to 24.7 inches.

The traveller in unexplored parts generally estimates his distances from the time taken at the average rate of marching, just as on board ship distances covered are roughly taken from the average rate of the ship indicated by the log. He takes compass bearings as he goes, and keeps an itinerary, recording all useful information gathered on the march. He corrects his reckoning by taking daily latitudes, and at greater intervals, say once a fortnight, longitudes from moon observations if he can. He notes heights, gets reports from natives of estimated distances, and in fact gathers all the information he can on every subject—rain-fall, botany, zoology, anthropology, and so forth. Livingstone did all these, and did them thoroughly. A whole lecture could be written on these maps I hold in my hand. Here is one of his notes:

"Eight days up this river 96 miles, then cross and go three days, say 36 miles, to stone houses 132 miles—course southwest Lobula, comes to northeast, has dark water."

A traveller with his wits about him can do much with very rough instruments, or even with none at all. He can train himself to use his fingers for rough angular measurements, and he can improvise in many ways. My own old chief, the late Col. W. B. Holmes, R. E., used to make wonderful surveys with his watch alone.

One great geographical problem—where does the huge river Sangpo, which flows in Tibet at the back of the Himalaya, discharge its waters?—was solved by a native surveyor, A. K., sent out by the Government of India, who was obliged to conceal all his observations. I quote from the official account:

"For linear measurement A. K. trusted entirely to his own pace or step, which, as hereafter shown, is convertible into the unit of a foot, or any other unit desired; and notwithstanding

that in Mongolia he was looked down upon as a particularly inferior individual, because, unlike the Mongols, he persisted in walking instead of following the universal custom of the country, which enjoins riding a horse on all possible occasions, he yet manfully strode along his travels, pleading poverty, or otherwise, until at last, on his return journey along the eastern flank of his route, the Lama with whom he had taken service insisted on his riding, if only to promote flight from robbers, especially the mounted bands of Chiámo-Goloks, of whom travellers are in constant dread. Thus compelled, A. K. mounted a horse, but here also he proved equal to the occasion, for he at once set to work counting the beast's paces as indicated by his stepping with the right foreleg. In this way he reckoned his distances for nearly 230 miles, between Bárong Chaidam (latitude 36° 5′, longitude 97° 3′), and Thuden Gomba (latitude 33° 17′, longitude 96° 43′), and the results do credit alike to the explorer's ingenuity and to the horse's equability of pace."

An account of his journey will be found in the *Scottish Geographical Magazine* for 1885, p. 352.

After the explorer comes the surveyor. His business is to produce a detailed survey or map of the country. The operations of a cadastral[1] survey on a grand scale, generally made by the Government, are divided into two parts: (1) the great triangular survey, and (2) the topographical part, or the filling in of the details required for civil information.

Before we go further we should gain a thorough idea of the principles of triangulation, because on it are founded all the conditions of an accurate map. The great property of a triangle is this, that of all plane geometrical figures it is the only one of which the form can not be altered if the sides remain constant, and that the three angles of a triangle are together equal to two right angles, so that if we know two of the angles of any triangle

[1] A cadastral survey is properly and etymologically a survey by a government for fiscal purposes, the word being derived from the low Latin *capitastrum*, a register for a poll tax. As such a survey was naturally carried out with the utmost completeness, the term "Cadastral Survey" came to be used equally with the term "Ordnance Survey" for the great Government survey of Great Britain and Ireland.

we can at once calculate the third angle by subtracting the number of degrees in the two known angles from 180 degrees, which is the sum of two right angles. If also we know the length of one of the sides of the triangle as well as the number of degrees in the angles, a very simple mathematical formula enables us to calculate the length of the other sides.

Now this is exactly what is done in the great trigonometrical survey made in this country by the Ordnance Survey: The surveyor measures what is called a *base line.* He purposely selects an absolutely horizontal plane otherwise conveniently situated for the purpose of measurement. The base line is seldom more than 5 or 6 miles long, but it is measured with "every refinement which ingenuity can devise or expense command." In the Ordnance Survey of the British Isles—to give an idea of the care with which such base lines are measured—the original base line, which was on Hounslow Heath, was measured in 1791, first with a steel chain, then with deal rods, next glass tubes, and lastly, again with the chain; and was over 5 miles long. Another line was subsequently measured 7 miles long, on Salisbury Plain, in 1794, which is the base of the existing triangulation. The verification line at Lough Foyle, which was 7 miles long, was measured with specially designed compound metal rods of brass and iron, 10 feet long, compensating like the balance and spring of a chronometer, so as to be independent of expansion and contraction, and their contact adjusted with microscopes. From this base once fixed, its latitude and longitude being most carefully taken, the surveyor measures the angles of suitably laid out triangles, and computes the length of their sides. Each of these sides in its turn becomes the base of a new triangle. The surveyor plants his instrument on the spot fixed on and measures new triangles, and gradually covers the surface of his island with a network of great triangles. The length of these sides are all calculated from the angles not measured, but, as a matter of fact, the lengths of these sides so computed from angular measurements are infinitely more accurate than if they were actually measured with a chain.

So accurate, indeed, was the triangulation of this country that

when the ordnance surveys verified their calculations thirty-three years after, in 1827, by actually measuring the check base on Lough Foyle, as already described, the greatest possible error was found to be less than 5 inches. This, be it remembered, was calculated from the base in Salisbury Plain, only 7 miles long, at a distance of over 300 miles. The mean length of the sides of the triangles was 35 miles, and the longest side was 111 miles. The history of the triangulation is quite a romance, but Sir Charles Wilson referred to all this at length last month.[1]

The instrument with which the angles are measured is the theodolite. This network of triangles so laid down is the backbone of all details of map-making. All these imaginary sides of triangles are, like the parallels of latitudes and meridians on large maps, the lines to which all filling in of detail is referred. Every point on this network is absolutely fixed, and from these points, as from the line of lamp-posts we considered at the beginning, all details are measured. The great triangulation in the Ordnance Survey being complete, the officers then lay off from the great triangles what are called secondary triangles, the sides of which are about 5 miles in length, and where necessary, tertiary triangles, with sides of about 1 mile in length, and from them the surveyor breaks up the interior of the triangle with a network of cross lines, all self-checking when laid on the paper, and this is the beginning of ordinary land survey.

The filling in of a survey is like writing a book. Men work differently. No two surveyors use exactly the same method of working, and it very much depends on the nature of the ground, the extent of his resources, and the accuracy of detail required what method the surveyor employs. In a theoretically perfect survey the triangular system would be pursued throughout, but in practice this is not necessary, nor is it done.

Of the methods of filling up, which are several, I will briefly describe two or three of the principal:

Traversing with the chain and theodolite.—A traverse is de-

[1] *The Scottish Geographical Magazine*, Vol. VII, p. 248. An admirable popular account of the operations of the Ordnance Survey will be found in *The Ordnance Survey of the United Kingdom*, by Lieut. Col. T. P. White, R. E. (Blackwood, 1886).

fined as a circuitous route performed on leaving any place on the earth's surface by stages in different directions and of various lengths with a view of arriving at any other place. The angles which the stages (or station lines) form with the meridian (*i. e.*, the north and south line) are called bearings. In other words, it is a walking from point to point in straight lines, always recording your distance and your direction.

These traverse lines are measured with the chain. They are generally laid out round the country to be surveyed, and are as multifarious as the necessities of the ground require. The bearings in a good permanent survey are measured with the theodolite, and when the traverse is complete it should be closed where begun, when, if no error is made, the bearing of the first line will read on the theodolite exactly as it read in the beginning. Cross checks and connecting lines are constantly taken to test the accuracy of the work, and while the survey is going on the measurements of all the features of the country are set down in what is called the field book. Where the line does not cross the natural features perpendiculars, called offsets, are set off and measured from the traverse line to the bends and angles of all surface details, bends of streams, fences, houses, roads, and so on, and so the map gets filled in bit by bit. Either it is set off at the beginning from the ordnance triangulation or subsequently joined to it by trigonometrical measurements. Such detail may be made piecemeal and fitted in like a Chinese puzzle to the main map of the country and altered or more minutely surveyed, according to requirements. For rapid and not very accurate purpose exactly the same methods may be adopted as for a military reconnoissance or sketch map by pacing the traverse lines and taking the bearings with the prismatic compass, and this is what is generally done in military sketches. All these operations and measurements are noted in a field book and are afterwards taken to the office and "plotted" on a sheet or sheets of paper.

There is also a contrivance for filling in a survey, with which no field book is used, but by which very fairly accurate work may be obtained. It is very little used in this country except for

military purposes, and then generally in a modified form shortly to be noticed; but it is much used for topographical work in India and on the continent and the United States. This instrument is the *plane table*. It serves itself as a theodolite, and the plan actually grows on the ground without after office work.

Contour lines.—A very important part of cadastral survey is the plotting on the map of contour lines, or lines of equal height. This is done after the features of the surface have been mapped. To draw the contour lines we must have a starting point, or, as it is called, a datum level. In our Ordnance Survey this is the level of the mean tide at Liverpool.

From the datum great lines and cross lines of levels are run all over the country, covering it with a network; and at all convenient spots the heights are permanently recorded by the well-known broad arrow, and called bench marks. Wherever the broad arrow is found engraved on the ground its height from the datum line will be found in the ordnance map of that part of the ground. A very common spot to find an ordnance bench mark is the keystone of the arch of the bridge, which would naturally be the last thing to be removed. These levels are got by spirit levelling. When the main levelling operations have been completed the surveyor fixes at what intervals of height his contours are to be drawn.

The surveyor starts, let us say, to determine the line at 100 feet above datum. He goes to the nearest bench mark he has to this height, say it is 105 feet. He levels down until he finds a point 5 feet below this bench mark. There he leaves a flag or a peg and goes on finding point after point at the same level; that is, he must read the same figure on the levelling staff. These points he then surveys as he would any natural feature, and permanently marks the imaginary lines joining them on the map, thereby showing a line of equal heights.

Military sketch or *reconnoissance* is a form of map which ought not to pass entirely undescribed. The object of a staff officer in making a sketch is to give such a representation of the nature of the ground as will give useful information to his general. It may take any amount of elaboration, may be as complete as

a cadastral survey taken with instruments of precision, or it may be merely the roughest indication of the nature of the ground, taken with such instruments as may be carried in the pocket, or even improvised without instruments, and be a mere eye sketch of the features of the ground. As the military information generally desired is the nature of the ground, whether suitable for maneuvering, for artillery, for cavalry, the nature of the roads, of the hills, of the rivers, should all be looked to, and rough contouring and hill shading is a very important part of the officer's work. He must also get information of defensible spots, of the water supplies, the food supplies, and the resources of the country, and this should be modified as much as possible on the plan or on the report attached to it.

Though any degree of elaborateness may be used, any instruments of precision employed, the typical military sketch is made with a sketching case, which is merely an improvised plane table. The main lines or traverses are taken from the bearings of the prismatic compass laid down on the sketch itself. The lines are generally paced or guessed, distant objects fixed by bearings from the station points, and the contouring measured angularly by Abney's level, or sketched by the eye. The shading of the hills shows steepness by the lines used to indicate them being drawn closer or farther apart.

The plans and maps having been drawn, and all notes made of information, they reach the cartographer or atlas-maker. His duty is first to compare all new information with what is already known; to eliminate manifest errors, to reduce to scale and to projection uniform with his great maps of the same part of the world, and generally to make everything ship-shape for publication.

Atlas-making.—I do not here refer to the Ordnance Survey maps, drawings, and prints, which were described with the utmost detail and precision by Sir Charles Wilson, but to the general atlases, such as Johnston's and Bartholomew's. With the information so gleaned the cartographer is able to make those beautiful orographical maps, which are now so common, showing different levels.

In our diagram I have colored the island orographically, which is done by drawing the contour lines and washing over the areas so marked with different variations of tint. But I shall not go far into this subject. Imagine the map drawn. It may be then engraved, like any other picture or line engraving, on a copper plate, and either printed from that plate or from lithographic stones, to which an impression of the plate has been transferred.

In the Ordnance Survey printing office, instead of lithographic stone, the maps are printed from sheets of zinc, which has much the same property of absorbing greasy ink.

By this time we have got into the printing office, and to describe it in detail would be beyond my province. This part of the subject, though very interesting, really embraces the whole art of the engraver, the lithographer, and the printer. But there is one process I desire to show before closing.

You see daily in books and newspapers, and in our own journal, maps printed in black along with the type. There are numberless processes for their production ; one only I shall briefly note. It is in the type-process of Messrs. Walker & Boutall, who have kindly sent me a specimen in course of manufacture.

On a brass plate a coating of a waxy composition is laid; the outlines of the map are either drawn on this coating or photographically transferred to it. The engraver then scratches through the wax down to the brass with a needle. He next takes suitable types and stamps in the names also drawn through the wax to the brass, and completes the matrix with the necessary amount of detail, which may be great or little. After verification and correction the matrix is ready for electrotyping. You who know the appearance of stereotype molds will see that this resembles the mold of an ordinary stereotype or electrotype page. The mold is next covered with black lead and an electrotype taken from it, when all the punctures that have been made through the wax to the level brass plate come out level—the scratches as lines and the type as lettering. It is then mounted

on wood, and is ready to insert among type and be printed along with it.

I have tried to give you very roughly an outline of how maps are made from the beginning to the end, in almost the same form that actual necessity forced me to learn it for practical use.

QUESTIONS AND EXERCISES

This selection, like the preceding, illustrates explanation of a process. In the case of the present selection, there is less suggestion of movement than in the account of the refining of oil. The stages of the process of map-making seem more distinctly separated, and spread out for examination. The steps in the process of oil refining seem to be more intimately connected and to pass into one another more rapidly.

1. Make an outline of the stages of map-making described in this selection. Has the writer proportioned his space well between these several stages? Should any part have fuller development?

2. How freely does he use definition? Give specific instances of its use.

3. By what means does the writer add interest to his explanation? Of what help are the diagrams?

Exercise 1. Explain one of the following processes clearly and fully. Use a diagram if necessary.

How moving picture films are made.
Preparing a speech.
Stuffing and mounting a bird.
Making tin cans.
Preparing a beetle for the cabinet.
How to find a book at the library.
Making a putting green.
How to patent an invention.
How books are made.
The preparation of photo-engravings.
Electrotyping.
The preparation of a modern newspaper.

EVOLUTION OF THE SCIENTIFIC INVESTIGATOR[1]

SIMON NEWCOMB

As we look at the assemblage gathered in this hall, comprising so many names of widest renown in every branch of learning—we might almost say in every field of human endeavor—the first inquiry suggested must be after the object of our meeting. The answer is that our purpose corresponds to the eminence of the assemblage. We aim at nothing less than a survey of the realm of knowledge, as comprehensive as is permitted by the limitations of time and space. The organizers of our congress have honored me with the charge of presenting such preliminary view of its field as may make clear the spirit of our undertaking.

Certain tendencies characteristic of the science of our day clearly suggest the direction of our thoughts most appropriate to the occasion. Among the strongest of these is one toward laying greater stress on questions of the beginning of things, and regarding a knowledge of the laws of development of any object of study as necessary to the understanding of its present form. It may be conceded that the principle here involved is as applicable in the broad field before us as in a special research into the properties of the minutest organism. It therefore seems meet that we should begin by inquiring what agency has brought about the remarkable development of science to which the world of to-day bears witness. This view is recognized in the plan of our proceedings by providing for each great department of knowledge a review of its progress during the century that has elapsed since the great event commemorated by the scenes outside this hall. But such reviews do not make up that general survey of science at large which is necessary to the development of our theme, and which must include the action of causes that had their origin

[1] Opening address at the International Congress of Arts and Science, St. Louis, September 19, 1904. Reprinted from *Popular Science Monthly*, Vol. LXVI., p. 92, by permission of the editor.

long before our time. The movement which culminated in making the nineteenth century ever memorable in history is the outcome of a long series of causes, acting through many centuries, which are worthy of especial attention on such an occasion as this. In setting them forth we should avoid laying stress on those visible manifestations which, striking the eye of every beholder, are in no danger of being overlooked, and search rather for those agencies whose activities underlie the whole visible scene, but which are liable to be blotted out of sight by the very brilliancy of the results to which they have given rise. It is easy to draw attention to the wonderful qualities of the oak; but, from that very fact, it may be needful to point out that the real wonder lies concealed in the acorn from which it grew.

Our inquiry into the logical order of the causes which have made our civilization what it is to-day will be facilitated by bringing to mind certain elementary considerations—ideas so familiar that setting them forth may seem like citing a body of truisms—and yet so frequently overlooked, not only individually, but in their relation to each other, that the conclusion to which they lead may be lost to sight. One of these propositions is that psychical rather than material causes are those which we should regard as fundamental in directing the development of the social organism. The human intellect is the really active agent in every branch of endeavor—the primum mobile of civilization—and all those material manifestations to which our attention is so often directed are to be regarded as secondary to this first agency. If it be true that "in the world is nothing great but man; in man is nothing great but mind," then should the keynote of our discourse be the recognition of this first and greatest of powers.

Another well-known fact is that those applications of the forces of nature to the promotion of human welfare which have made our age what it is are of such comparatively recent origin that we need go back only a single century to antedate their most important features, and scarcely more than four centuries to find their beginning. It follows that the subject of our inquiry

should be the commencement, not many centuries ago, of a certain new form of intellectual activity.

Having gained this point of view, our next inquiry will be into the nature of that activity and its relation to the stages of progress which preceded and followed its beginning. The superficial observer, who sees the oak but forgets the acorn, might tell us that the special qualities which have brought out such great results are expert scientific knowledge and rare ingenuity, directed to the application of the powers of steam and electricity. From this point of view the great inventors and the great captains of industry were the first agents in bringing about the modern era. But the more careful inquirer will see that the work of these men was possible only through a knowledge of the laws of nature, which had been gained by men whose work took precedence of theirs in logical order, and that success in invention has been measured by completeness in such knowledge. While giving all due honor to the great inventors, let us remember that the first place is that of the great investigators, whose forceful intellects opened the way to secrets previously hidden from men. Let it be an honor and not a reproach to these men that they were not actuated by the love of gain, and did not keep utilitarian ends in view in the pursuit of their researches. If it seems that in neglecting such ends they were leaving undone the most important part of their work, let us remember that nature turns a forbidding face to those who pay her court with the hope of gain, and is responsive only to those suitors whose love for her is pure and undefiled. Not only is the special genius required in the investigator not that generally best adapted to applying the discoveries which he makes, but the result of his having sordid ends in view would be to narrow the field of his efforts and exercise a depressing effect upon his activities. The true man of science has no such expression in his vocabulary as "useful knowledge." His domain is as wide as nature itself, and he best fulfills his mission when he leaves to others the task of applying the knowledge he gives to the world.

We have here the explanation of the well-known fact that the functions of the investigator of the laws of nature and of the

inventor who applies these laws to utilitarian purposes are rarely united in the same person. If the one conspicuous exception which the past century presents to this rule is not unique, we should probably have to go back to Watt to find another.

From this viewpoint it is clear that the primary agent in the movement which has elevated man to the masterful position he now occupies is the scientific investigator. He it is whose work has deprived plague and pestilence of their terrors, alleviated human suffering, girdled the earth with the electric wire, bound the continent with the iron way, and made neighbors of the most distant nations. As the first agent which has made possible this meeting of his representatives, let his evolution be this day our worthy theme. As we follow the evolution of an organism by studying the stages of its growth, so we have to show how the work of the scientific investigator is related to the ineffectual efforts of his predecessors.

In our time we think of the process of development in nature as one going continuously forward through the combination of the opposite processes of evolution and dissolution. The tendency of our thought has been in the direction of banishing cataclysms to the theological limbo and viewing nature as a sleepless plodder, endowed with infinite patience, waiting through long ages for results. I do not contest the truth of the principle of continuity on which this view is based. But it fails to make known to us the whole truth. The building of a ship from the time that her keel is laid until she is making her way across the ocean is a slow and gradual process; yet there is a cataclysmic epoch opening up a new era in her history. It is the moment when, after lying for months or years a dead, inert, immovable mass, she is suddenly endowed with the power of motion, and, as if imbued with life, glides into the stream, eager to begin the career for which she was designed.

I think it is thus in the development of humanity. Long ages may pass during which a race, to all external observation, appears to be making no real progress. Additions may be made to learning and the records of history may constantly grow, but there is nothing in its sphere of thought or in the features of its

life that can be called essentially new. Yet nature may have been all along slowly working in a way which evades our scrutiny until the result of her operations suddenly appears in a new and revolutionary movement, carrying the race to a higher plane of civilization.

It is not difficult to point out such epochs in human progress. The greatest of all, because it was the first, is one of which we find no record either in written or geological history. It was the epoch when our progenitors first took conscious thought of the morrow, first used the crude weapons which nature had placed within their reach to kill their prey, first built a fire to warm their bodies and cook their food. I love to fancy that there was some one first man, the Adam of evolution, who did all this, and who used the power thus acquired to show his fellows how they might profit by his example. When the members of the tribe or community which he gathered around him began to conceive of life as a whole—to include yesterday, to-day, and to-morrow in the same mental grasp—to think how they might apply the gifts of nature to their own uses, a movement was begun which should ultimately lead to civilization.

Long indeed must have been the ages required for the development of this rudest primitive community into the civilization revealed to us by the most ancient tablets of Egypt and Assyria. After spoken language was developed, and after the rude representation of ideas by visible marks drawn to resemble them had long been practiced, some Cadmus must have invented an alphabet. When the use of written language was thus introduced, the word of command ceased to be confined to the range of the human voice, and it became possible for master minds to extend their influence as far as a written message could be carried. Then were communities gathered into provinces, provinces into kingdoms, kingdoms into the great empires of antiquity. Then arose a stage of civilization which we find pictured in the most ancient records—a stage in which men were governed by laws that were perhaps as wisely adapted to their conditions as our laws are to ours—in which the phenomena

of nature were rudely observed, and striking occurrences in the earth or in the heavens recorded in the annals of the nation.

Vast was the progress of knowledge during the interval between these empires and the century in which modern science began. Yet, if I am right in making a distinction between the slow and regular steps of progress, each growing naturally out of that which preceded it, and the entrance of the mind at some fairly definite epoch into an entirely new sphere of activity, it would appear that there was only one such epoch during the entire interval. This was when abstract geometrical reasoning commenced, and astronomical observations aiming at precision were recorded, compared, and discussed. Closely associated with it must have been the construction of the forms of logic. The radical difference between the demonstration of a theorem of geometry and the reasoning of everyday life which the masses of men must have practiced from the beginning, and which few even to-day ever get beyond, is so evident at a glance that I need not dwell upon it. The principal feature of this advance is that, by one of those antinomies of the human intellect of which examples are not wanting even in our time, the development of abstract ideas preceded the concrete knowledge of natural phenomena. When we reflect that in the geometry of Euclid the science of space was brought to such logical perfection that even to-day its teachers are not agreed as to the practicability of any great improvement upon it, we can not avoid the feeling that a very slight change in the direction of the intellectual activity of the Greeks would have led to the beginning of natural science. But it would seem that the very purity and perfection which was aimed at in their system of geometry stood in the way of any extension or application of its methods and spirit to the field of nature. One example of this is worthy of attention. In modern teaching the idea of magnitude as generated by motion is freely introduced. A line is described by a moving point; a plane by a moving line; a solid by a moving plane. It may, at first sight, seem singular that this conception finds no place in the Euclidian system. But we may regard the omission as a mark of logical purity and rigor. Had

the real or supposed advantages of introducing motion into geometrical conceptions been suggested to Euclid, we may suppose him to have replied that the theorems of space are independent of time; that the idea of motion necessarily implies time, and that, in consequence, to avail ourselves of it would be to introduce an extraneous element into geometry.

It is quite possible that the contempt of the ancient philosophers for the practical application of their science, which has continued in some form to our own time, and which is not altogether unwholesome, was a powerful factor in the same direction. The result was that, in keeping geometry pure from ideas which did not belong to it, it failed to form what might otherwise have been the basis of physical science. Its founders missed the discovery that methods similar to those of geometric demonstration could be extended into other and wider fields than that of space. Thus, not only the development of applied geometry, but the reduction of other conceptions to a rigorous mathematical form was indefinitely postponed.

Astronomy is necessarily a science of observation pure and simple, in which experiment can have no place except as an auxiliary. The vague accounts of striking celestial phenomena handed down by the priests and astrologers of antiquity were followed in the time of the Greeks by observations having, in form at least, a rude approach to precison, though nothing like the degree of precision that the astronomer of to-day would reach with the naked eye, aided by such instruments as he could fashion from the tools at the command of the ancients.

The rude observations commenced by the Babylonians were continued with gradually improving instruments—first by the Greeks and afterwards by the Arabs—but the results failed to afford any insight into the true relation of the earth to the heavens. What was most remarkable in this failure is that, to take a first step forward which would have led on to success, no more was necessary than a course of abstract thinking vastly easier than that required for working out the problems of geometry. That space is infinite is an unexpressed axiom, tacitly assumed by Euclid and his successors. Combining this with

the most elementary consideration of the properties of the triangle, it would be seen that a body of any given size could be placed at such a distance in space as to appear to us like a point. Hence, a body as large as our earth, which was known to be a globe from the time that the ancient Phœnicians navigated the Mediterranean, if placed in the heavens at a sufficient distance, would look like a star. The obvious conclusion that the stars might be bodies like our globe, shining either by their own light or by that of the sun, would have been a first step to the understanding of the true system of the world.

There is historic evidence that this deduction did not wholly escape the Greek thinkers. It is true that the critical student will assign little weight to the current belief that the vague theory of Pythagoras—that fire was at the center of all things—implies a conception of the heliocentric theory of the solar system. But the testimony of Archimedes, confused though it is in form, leaves no serious doubt that Aristarchus of Samos not only propounded the view that the earth revolves both on its own axis and around the sun, but that he correctly removed the great stumbling-block in the way of this theory by adding that the distance of the fixed stars was infinitely greater than the dimensions of the earth's orbit. Even the world of philosophy was not yet ready for this conception, and, so far from seeing the reasonableness of the explanation, we find Ptolemy arguing against the rotation of the earth on grounds which careful observations of the phenomena around him would have shown to be ill-founded.

Physical science, if we can apply that term to an uncoordinated body of facts, was successfully cultivated from the earliest times. Something must have been known of the properties of metals, and the art of extracting them from their ores must have been practiced from the time that coins and metals were first stamped. The properties of the most common compounds were discovered by alchemists in their vain search for the philosopher's stone, but no actual progress worthy of the name rewarded the practitioners of the black art.

Perhaps the first approach to a correct method was that of

Archimedes, who by much thinking worked out the law of the lever, reached the conception of the center of gravity, and demonstrated the first principles of hydrostatics. It is remarkable that he did not extend his researches into the phenomena of motion, whether spontaneous or produced by force. The stationary condition of the human intellect is most strikingly illustrated by the fact that not until the time of Leonardo was any substantial advance made on his discovery. To sum up in one sentence the most characteristic feature of ancient and mediæval science, we see a notable contrast between the precision of thought implied in the construction and demonstration of geometrical theorems and the vague indefinite character of the ideas of natural phenomena generally, a contrast which did not disappear until the foundations of modern science began to be laid.

We should miss the most essential point of the difference between mediæval and modern learning if we looked upon it as mainly a difference either in the precision or the amount of knowledge. The development of both of these qualities would, under any circumstances, have been slow and gradual, but sure. We can hardly suppose that any one generation, or even any one century, would have seen the complete substitution of exact for inexact ideas. Slowness of growth is as inevitable in the case of knowledge as in that of a growing organism. The most essential point of difference is one of those seemingly slight ones, the importance of which we are too apt to overlook. It was like the drop of blood in the wrong place, which some one has told us makes all the difference between a philosopher and a maniac. It was all the difference between a living tree and a dead one, between an inert mass and a growing organism. The transition of knowledge from the dead to the living form must, in any complete review of the subject, be looked upon as the really great event of modern times. Before this event the intellect was bound down by a scholasticism which regarded knowledge as a rounded whole, the parts of which were written in books and carried in the minds of learned men. The student was

taught from the beginning of his work to look upon authority as the foundation of his beliefs. The older the authority the greater the weight it carried. So effective was this teaching that it seems never to have occurred to individual men that they had all the opportunities ever enjoyed by Aristotle of discovering truth, with the added advantage of all his knowledge to begin with. Advanced as was the development of formal logic, that practical logic was wanting which could see that the last of the series of authorities, every one of which rested on those which preceded it, could never form a surer foundation for any doctrine than that supplied by its original propounder.

The result of this view of knowledge was, that although during the fifteen centuries following the death of the geometer of Syracuse great universities were founded at which generations of professors expounded all the learning of their time, neither professor nor student ever suspected what latent possibilities of good were concealed in the most familiar operations of nature. Everyone felt the wind blow, saw water boil, and heard the thunder crash, but never thought of investigating the forces here at play. Up to the middle of the fifteenth century the most acute observer could scarcely have seen the dawn of a new era.

In view of this state of things, it must be regarded as one of the most remarkable facts in evolutionary history that four or five men, whose mental constitution was either typical of the new order of things or who were powerful agents in bringing it about, were all born during the fifteenth century, four of them at least at so nearly the same time as to be contemporaries.

Leonardo da Vinci, whose artistic genius has charmed succeeding generations, was also the first practical engineer of his time, and the first man after Archimedes to make a substantial advance in developing the laws of motion. That the world was not prepared to make use of his scientific discoveries does not detract from the significance which must attach to the period of his birth.

Shortly after him was born the great navigator whose bold spirit was to make known a new world, thus giving to commer-

cial enterprise that impetus which was so powerful an agent in bringing about a revolution in the thoughts of men.

. The birth of Columbus was soon followed by that of Copernicus, the first after Aristarchus to demonstrate the true system of the world. In him more than in any of his contemporaries do we see the struggle between the old forms of thought and the new. It seems almost pathetic, and is certainly most suggestive of the general view of knowledge taken at that time, that instead of claiming credit for bringing to light great truths before unknown he made a labored attempt to show that after all there was nothing really new in his system, which he claimed to date from Pythagoras and Philolaus. In this connection it is curious that he makes no mention of Aristarchus, who, I think, will be regarded by conservative historians as his only demonstrated predecessor. To the hold of the older ideas upon his mind we must attribute the fact that in constructing his system he took great pains to make as little change as possible in ancient conceptions.

Luther, the greatest thought stirrer of them all, practically of the same generation with Copernicus, Leonardo, and Columbus, does not come in as a scientific investigator, but as the great loosener of chains which had so fettered the intellect of men that they dared not think otherwise than as the authorities thought.

Almost coeval with the advent of these intellects was the invention of printing with movable type. Gutenberg was born during the first decade of the century, and his associates and others credited with the invention not many years afterwards. If we accept the principle on which I am basing my argument, that we should assign the first place to the birth of those psychic agencies which started men on new lines of thought, then surely was the fifteenth the wonderful century.

Let us not forget that, in assigning the actors then born to their places, we are not narrating history, but studying a special phase of evolution. It matters not for us that no university invited Leonardo to its halls, and that his science was valued by his contemporaries only as an adjunct to the art of engineering. The great fact still is that he was the first of mankind to

propound laws of motion. It is not for anything in Luther's doctrines that he finds a place in our scheme. No matter for us whether they were sound or not. What he did toward the evolution of the scientific investigator was to show by his example that a man might question the best-established and most venerable authority and still live, still preserve his intellectual integrity, still command a hearing from nations and their rulers. It matters not for us whether Columbus ever knew that he had discovered a new continent. His work was to teach that neither hydra, chimera, nor abyss—neither divine injunction nor infernal machination—was in the way of men visiting every part of the globe, and that the problem of conquering the world reduced itself to one of sails and rigging, hull and compass. The better part of Copernicus was to direct man to a view point whence he should see that the heavens were of like matter with the earth. All this done, the acorn was planted from which the oak of our civilization should spring. The mad quest for gold which followed the discovery of Columbus, the questionings which absorbed the attention of the learned, the indignation excited by the seeming vagaries of a Paracelsus, the fear and trembling lest the strange doctrine of Copernicus should undermine the faith of centuries, were all helps to the germination of the seed—stimuli to thought which urged it on to explore the new fields opened up to its occupation. This given, all that has since followed came out in regular order of development, and need be here considered only in those phases having a special relation to the purpose of our present meeting.

So slow was the growth at first that the sixteenth century may scarcely have recognized the inauguration of a new era. Torricelli and Benedetti were of the third generation after Leonardo, and Galileo, the first to make a substantial advance upon his theory, was born more than a century after him. Only two or three men appeared in a generation who, working alone, could make real progress in discovery, and even these could do little in leavening the minds of their fellow-men with the new ideas.

Up to the middle of the seventeenth century an agent which

all experience since that time shows to be necessary to the most productive intellectual activity was wanting. This was the attrition of like minds, making suggestions to each other, criticizing, comparing, and reasoning. This element was introduced by the organization of the Royal Society of London and the Academy of Sciences of Paris.

The members of these two bodies seem like ingenious youth suddenly thrown into a new world of interesting objects, the purposes and relations of which they had to discover. The novelty of the situation is strikingly shown in the questions which occupied the minds of the incipient investigators. One natural result of British maritime enterprise was that the aspirations of the Fellows of the Royal Society were not confined to any continent or hemisphere. Inquiries were sent all the way to Batavia to know "whether there be a hill in Sumatra which burneth continually and a fountain which runneth pure balsam." The astronomical precision with which it seemed possible that physiological operations might go on was evinced by the inquiry whether the Indians can so prepare that stupefying herb Datura that "they make it lie several days, months, years, according as they will, in a man's body without doing him any harm, and at the end kill him without missing an hour's time." Of this continent one of the inquiries was whether there be a tree in Mexico that yields water, wine, vinegar, milk, honey, wax, thread, and needles.

Among the problems before the Paris Academy of Sciences those of physiology and biology took a prominent place. The distillation of compounds had long been practiced, and the fact that the more spirituous elements of certain substances were thus separated naturally led to the question whether the essential essences of life might not be discoverable in the same way. In order that all might participate in the experiments they were conducted in open session of the academy, thus guarding against the danger of any one member obtaining for his exclusive personal use a possible elixir of life. A wide range of the animal and vegetable kingdom, including cats, dogs, and birds of various species, were thus analyzed. The practice of dissection

was introduced on a large scale. That of the cadaver of an elephant occupied several sessions, and was of such interest that the monarch himself was a spectator.

To the same epoch with the formation and first work of these two bodies belongs the invention of a mathematical method which in its importance to the advance of exact science may be classed with the invention of the alphabet in its relation to the progress of society at large. The use of algebraic symbols to represent quantities had its origin before the commencement of the new era, and gradually grew into a highly developed form during the first two centuries of that era. But this method could represent quantities only as fixed. It is true that the elasticity inherent in the use of such symbols permitted of their being applied to any and every quantity; yet, in any one application, the quantity was considered as fixed and definite. But most of the magnitudes of nature are in a state of continual variation; indeed, since all motion is variation, the latter is a universal characteristic of all phenomena. No serious advance could be made in the application of algebraic language to the expression of physical phenomena until it could be so extended as to express variation in quantities, as well as the quantities themselves. This extension, worked out independently by Newton and Leibnitz, may be classed as the most fruitful of conceptions in exact science. With it the way was opened for the unimpeded and continually accelerated progress of the two last centuries.

The feature of this period which has the closest relation to the purpose of our coming together is the seemingly unending subdivision of knowledge into specialties, many of which are becoming so minute and so isolated that they seem to have no interest for any but their few pursuers. Happily science itself has afforded a corrective for its own tendency in this direction. The careful thinker will see that in these seemingly diverging branches common elements and common principles are coming more and more to light. There is an increasing recognition of methods of research and of deduction which are common to large branches or to the whole of science. We are more and more recognizing the principle that progress in knowledge im-

plies its reduction to more exact forms, and the expression of its ideas in language more or less mathematical. The problem before the organizers of this congress was, therefore, to bring the sciences together and seek for the unity which we believe underlies their infinite diversity.

The assembling of such a body as now fills this hall was scarcely possible in any preceding generation, and is made possible now only through the agency of science itself. It differs from all preceding international meetings by the universality of its scope, which aims to include the whole of knowledge. It is also unique in that none but leaders have been sought out as members. It is unique in that so many lands have delegated their choicest intellects to carry on its work. They come from the country to which our Republic is indebted for a third of its territory, including the ground on which we stand; from the land which has taught us that the most scholarly devotion to the languages and learning of the cloistered past is compatible with leadership in the practical application of modern science to the arts of life; from the island whose language and literature have found a new field and a vigorous growth in this region; from the last seat of the holy Roman Empire; from the country which, remembering a monarch who made an astronomical observation at the Greenwich Observatory, has enthroned science in one of the highest places in its government; from the peninsula so learned that we have invited one of its scholars to come and tell us of our own language; from the land which gave birth to Leonardo, Galileo, Torricelli, Columbus, Volta—what an array of immortal names!—from the little republic of glorious history which, breeding men rugged as its eternal snow peaks, has yet been the seat of scientific investigation since the day of the Bernoullis; from the land whose heroic dwellers did not hesitate to use the ocean itself to protect it against invaders, and which now makes us marvel at the amount of erudition compressed within its little area; from the nation across the Pacific, which by half a century of unequaled progress in the arts of life has made an important contribution to evolutionary science through demonstrating the falsity of the theory that

the most ancient races are doomed to be left in the rear of the advancing age—in a word, from every great center of intellectual activity on the globe I see before me eminent representatives of that world advance in knowledge which we have met to celebrate. May we not confidently hope that the discussions of such an assemblage will prove pregnant of a future for science which shall outshine even its brilliant past?

Gentlemen and scholars all, you do not visit our shores to find great collections in which centuries of humanity have given expression on canvas and in marble to their hopes, fears, and aspirations. Nor do you expect institutions and buildings hoary with age. But as you feel the vigor latent in the fresh air of these expansive prairies, which has collected the products of human genius by which we are here surrounded, and, I may add, brought us together; as you study the institutions which we have founded for the benefit not only of our own people, but of humanity at large; as you meet the men who, in the short space of one century, have transformed this valley from a savage wilderness into what it is to-day, then may you find compensation for the want of a past like yours by seeing with prophetic eye a future world power of which this region shall be the seat. If such is to be the outcome of the institutions which we are now building up, then may your present visit be a blessing both to your posterity and ours by making that power one for good to all mankind. Your deliberations will help to demonstrate to us and to the world at large that the reign of law must supplant that of brute force in the relations of the nations, just as it has supplanted it in the relations of individuals. You will help to show that the war which science is now waging against the sources of diseases, pain, and misery offers an even nobler field for the exercise of heroic qualities than can that of battle. We hope that when, after your all too fleeting sojourn in our midst, you return to your own shores you will long feel the influence of the new air you have breathed in an infusion of increased vigor in pursuing your varied labors. And if a new impetus is thus given to the great intellectual movement of the past century, resulting not only in promoting the unifica-

tion of knowledge, but in widening its field through new combinations of effort on the part of its votaries, the projectors, organizers, and supporters of this Congress of Arts and Science will be justified of their labors.

QUESTIONS AND EXERCISES

In this selection, Newcomb was primarily concerned in showing the causes that have led up to the astonishing results of modern science. As his task forces him to cover a long stretch of history, it is simpler to follow the order in which the successive developments occurred.

1. Point out the different stages in the evolution of the scientific investigator. Does the writer lead easily from one stage to another? Is it evident to the reader what the main causes of the development of modern science are, or would it have been better for the writer to explain these by some other method than the chronological?

Exercise 1. Write in imitation of Newcomb's method an essay on one of the following topics, or some other similar subject. Develop the topic chronologically, but keep in mind the purpose of showing the causes underlying these developments.

The development of the automobile.
Attempts to dig the Panama Canal.
Evolution of the American college.
History of money.
Modifications in the game of foot-ball.
The development of electric railroads.
The development of steam navigation.
Progress in internal combustion engines.
Growth of democracy in the nineteenth century.

Exercise 2. Trace, after the manner of Newcomb's discussion, the evolution of some science or profession, such as chemistry, physics, civil engineering.

The Short-Story: Its Principles and Its Structure

By EVELYN MAY ALBRIGHT

Assistant Professor of English, Ohio Wesleyan University

Small 12mo, 260 pages, 90 cents net.

It is all the better for the amateur that Miss Albright has prepared her book in the orderly manner required for teaching classes, and with the needs of the inexperienced pupil in mind. She follows the scientific method of analyzing works of recognized character, and thus setting forth the distinguishing features of the modern short-story, with many suggestions as to the details and the general principles of narrative construction. References are made to recent magazine literature, as well as to a large number of recognized masterpieces. In other words, the author undertakes to set forth standards of appreciation of what is *good* in story-writing, illustrating by the practice of the masters as contrasted with amateurish failures. The result, in the mind of an attentive student, is a more lively interest in his reading, and the awakening of an intelligent spirit of criticism toward his own work.

Descriptive Writing

By EVELYN MAY ALBRIGHT

Cloth, 12mo, 275 pages, $1.25 net.

Miss Albright very sensibly takes up the problems of description in the order in which they naturally occur to a writer, beginning with the search for material, proceeding then to the working over of the material, and finally discussing the more minute considerations, such as diction and style. She also considers description in its actual relation to other kinds of writing—its service to exposition, and more particularly, to narration. A wide range of illustrations is provided for classroom use, as it is believed that a study of good models should not be neglected. The book is designed for use as a text in college courses in composition. It is suggested further that it may be of service in the daily theme courses, as an assignment of descriptive composition is peculiarly convenient owing to the ease with which students may find for themselves fresh and varied material, and to the possibility of securing at the same time brevity and finish.

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